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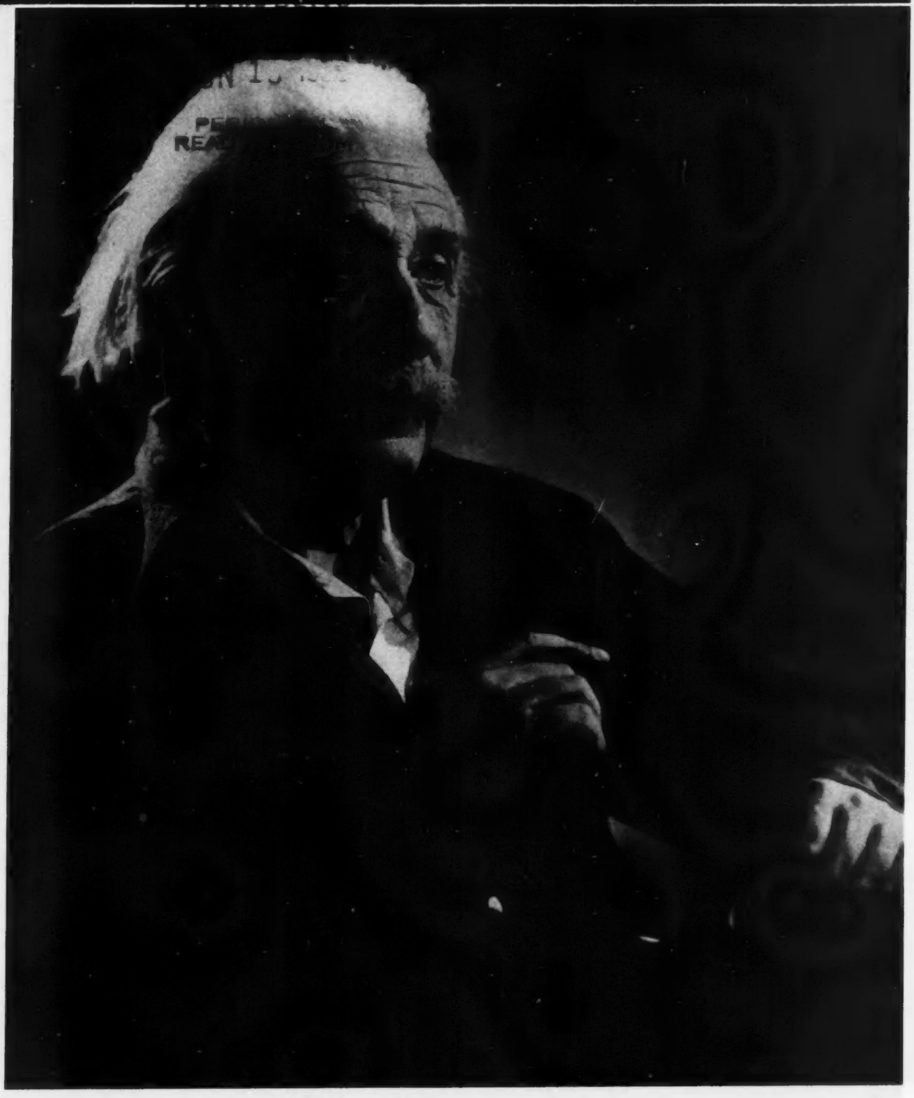

Albert Einstein (1879–1955)

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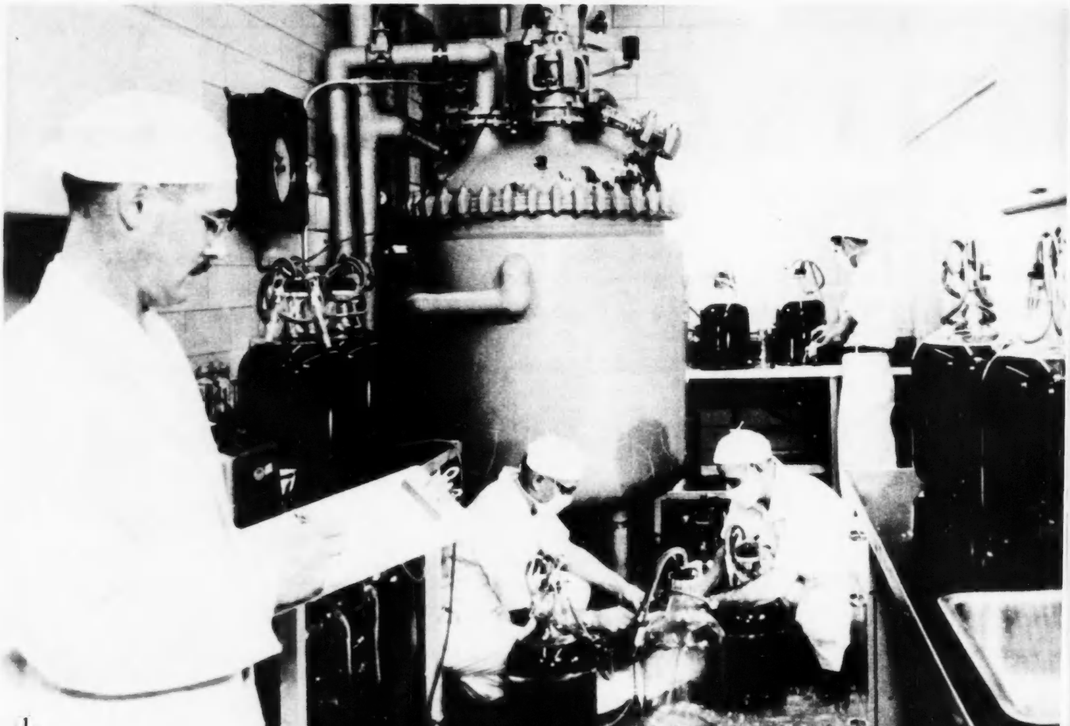
THE AMERICAN POLIO VACCINE

In human beings and monkeys poliomyelitis virus is concentrated almost entirely in two main situations—in the intestine, and in cells in the central nervous system, where the cellular damage caused gives rise to the symptoms which give this disease its more familiar name of infantile paralysis. In tissue culture, however, the virus is less fastidious in its choice of suitable cells.

In 1950 Enders, Robbins and Weller, working at the Children's Hospital at Boston, showed that poliomyelitis virus could be grown in tissue cultures of human embryonic skin, and that visible destruction of cells in the cultures was accompanied by the appearance of increased quantities of virus in the liquid part of the cultures. This was the discovery for which these three workers were later awarded a Nobel Prize in 1954. Subsequently, it was shown that cells from the testicle and the kidney—from monkeys as well as humans—can support the growth of poliomyelitis virus in tissue cultures. The fluid phase of such cultures, particularly when monkey kidney tissue is used, contains large amounts of virus. This can be readily treated with formaldehyde in such a way that it loses its ability to infect monkeys or further tissue cultures, but will still cause the production of antibodies against poliomyelitis virus when injected into animals or men. Such a vaccine based on the killed virus was tried out on a large scale against poliomyelitis in the U.S.A. in 1954, and the results of the trial were announced this April. Dr. Jonas E. Salk, of the University of Pittsburgh, was generally responsible for the development of the vaccine used in this large-scale trial. He had previously shown that monkeys injected with virus cultivated in tissue culture and then killed by formaldehyde were subsequently immune to injections of live virus. Later, in 1953, he also showed that in about eight thousand human beings injection with the inactive virus gave them antibodies when they had none, or else greatly increased the amount of already existing antibody.

1,800,000 children were involved in the 1954 trial of the Salk vaccine, coming from 211 different areas in 44 out of the 48 States of the U.S.A. Children were inoculated in April, May, and June—before the onset of the poliomyelitis season—and carefully observed during the summer months. The incidence of poliomyelitis was then compared between comparable age-groups of children which either had, or had not, been given the vaccine. No untoward effects of vaccination were observed, there being only a small percentage of minor side reactions to the vaccine; no cases of poliomyelitis attributable to the vaccine occurred. The vaccine had no effect on the incidence of the non-paralytic form of the disease. It had, on the other hand, a considerable effect on the incidence of paralysis. In one set of areas 200,000 vaccinated children were compared with a similar number who had received dummy inoculations—that is, comparable injections which did not contain formaldehyde-killed polio virus. 115 cases of paralysis and 4 deaths occurred among those receiving dummy injections; in the vaccinated group there were only 33 cases of paralytic disease and no deaths.

In a second study a comparison was made between 220,000 vaccinated children and 860,000 of the same age who received no injections, but who were carefully observed for the duration of the trial. The children vaccinated during the trial were each given three injections of the Salk vaccine spaced two weeks apart. (Dr. Salk has since stated that a favourable antibody response is also obtained when only two such injections are given, followed by a third "booster" dose at least seven months later.) In the untreated population 330 cases of paralytic poliomyelitis occurred with 11 deaths; among the vaccinated children there were only 38 paralytic cases and no deaths. Allowing for the difference in the size of these two last populations, these figures reduce to something like those of the other study; namely, that for that small proportion of the total population studied who contracted paralytic polio, their chances of avoiding paralysis are three times better with the vaccine than without it. The vaccine proved particularly effective

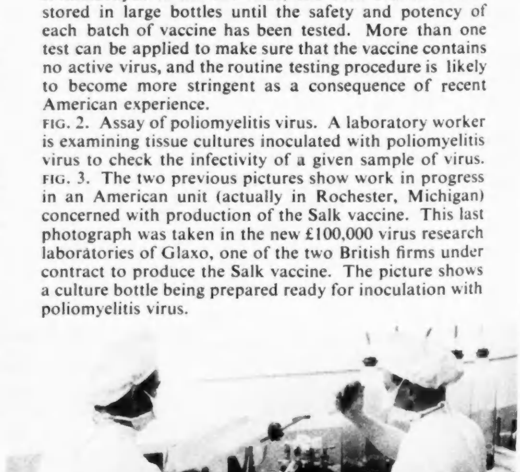


PRODUCTION OF THE SALK POLIO VACCINE

FIG. 1. The basis of the Salk vaccine is a mixture of all three immunological types of poliomyelitis virus. These are grown separately. In this picture, the three different tissue-culture fluids are pooled in the large storage tank in the background. The material is then treated with formaldehyde to kill the virus, and then drawn off and stored in large bottles until the safety and potency of each batch of vaccine has been tested. More than one test can be applied to make sure that the vaccine contains no active virus, and the routine testing procedure is likely to become more stringent as a consequence of recent American experience.

FIG. 2. Assay of poliomyelitis virus. A laboratory worker is examining tissue cultures inoculated with poliomyelitis virus to check the infectivity of a given sample of virus.

FIG. 3. The two previous pictures show work in progress in an American unit (actually in Rochester, Michigan) concerned with production of the Salk vaccine. This last photograph was taken in the new £100,000 virus research laboratories of Glaxo, one of the two British firms under contract to produce the Salk vaccine. The picture shows a culture bottle being prepared ready for inoculation with poliomyelitis virus.



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against the severe bulbar form of the disease, which is often fatal, and also had a striking protective effect against paralytic polio contracted from family contacts.

However, while the results of the trial have established that a vaccine consisting of killed virus can produce a measure of protection against paralysis under field conditions, a further period of testing will undoubtedly be necessary before it is advisable to use the vaccine indiscriminately all over the world. For example, very little is known about the duration of the immunity conferred by the killed virus vaccine. Measurements of the amount of antibody present in the serum of vaccinated children have shown that this had undergone a significant decline only five months after vaccination, and it is possible that vaccinated individuals may have to be given periodic booster doses of vaccine in order to maintain antibody production at a high level. In this connexion it is important that the tissue cultures in which the vaccine virus is grown consist of monkey kidney, and the vaccine therefore contains monkey kidney protein as well as virus. Some individuals become sensitised to foreign protein and develop serious allergies to it. While the proportion of reactions to the vaccine in the trial was extremely small, there is no guarantee that this will remain the case when repeated booster inoculations have to be given to large numbers of people.

Even if such difficulties prove negligible there is still some doubt whether universal vaccination is the best way of preventing polio in the end. Under natural conditions of infection for each potential paralytic there are hundreds who become infected without ever showing significant symptoms. As we cannot at the moment detect the potentially paralytic individual in advance, we must vaccinate a very large number who would never have become paralysed in order to prevent paralysis in the one who is really threatened. The figures of the trial show that in the U.S.A. it is necessary to vaccinate nearly 4000 individuals to protect each potential paralytic. In Britain, where the overall paralytic rate is lower, up to five times that number of vaccinations might be necessary; and in a primitive community, where the infection rate is high, but the paralytic rate very low indeed, many hundreds of thousands of inoculations might be necessary to protect each vulnerable individual. Not only would the cost of such a project be formidable, but the small number of adverse reactions encountered might well assume significance when compared with the number of potential paralyses prevented.

However, until other possible types of polio vaccine—such as those involving living but non-virulent virus—have been further investigated, the Salk vaccine remains the only practicable method of poliomyelitis control. However, a long period of careful testing of its effectiveness under different conditions is still undoubtedly necessary. Until we know more about its effects, it should be used primarily in situations where its use, on the present evidence, would be most beneficial, such as in areas where there is known to be a high paralytic rate, or to protect particularly vulnerable individuals—such as those known already to lack basal immunity to one or more of the three types of poliomyelitis virus.

Two firms in Britain, Glaxo Laboratories Ltd. and Burroughs Wellcome, had already started making the vaccine on a small scale before the Francis report on the American trials was published, but a hitch has arisen through a curtailment of the supply of monkeys and this has affected the production programme. Various explanations have been offered for this. Certainly the embargo placed by the Indian Government on the export of monkeys was a relevant factor, but that has now been raised. There has, however, been a lot of talk to the effect that the powerful American industrial interests concerned with the production of the Salk vaccine had almost completely cornered the market in monkeys. The first small-scale trial of the vaccine is almost certain to be delayed even though the production position in Britain may improve in the very near future, and though officially this trial is supposed to start this year it may have to be delayed until early in 1956. It has been decided that it is necessary to make a further scientific trial of the vaccine before using it for routine vaccination purposes, for the good reason that polio virus seems to behave in Britain in a slightly different way and the results of the American trial may not be directly applicable here. For example, not only is the paralytic rate lower, but the predominant attack is upon younger children, whose response to the vaccine we do not yet know. Also the three types of virus occur here in rather different proportions from their distribution in the U.S.A. The trial here will be conducted under the direction of the Medical Research Council.

NEW LIGHT ON PHOTOSYNTHESIS

Some of the most active biochemical research today centres on a natural process which is the most important piece of synthesis occurring on this earth. This vital process, which is called photosynthesis, is performed only by green plants, and if it were to stop life as we know it would disappear.

Very little was known about the details of the mechanism of photosynthesis, however, until some twenty years ago, but in that period, and particularly in the last decade, so much has been discovered about it that it is now possible to reproduce parts of the process in the test tube in the absence of living material.

Photosynthesis is the conversion of the simple gas, carbon dioxide (CO_2), into sugar and similar complex organic compounds by plants in the presence of sunlight. Many people suppose that plants get all their food from the soil, but this is not so. A plant gets the water it needs from the soil, together with nitrate ions and various elements in small amounts, but only a minor proportion of the total solid material of plants can be accounted for in this way; the rest is made up of compounds (e.g. carbohydrates, proteins, fats) which contain large amounts of the elements carbon and oxygen, and the plant makes these from the carbon dioxide which it absorbs from the air. Green plants produce two hundred thousand million tons of organic material in this way every year. This is well over one hundred times the

combined output of all the chemical, metallurgical and the mining industries in the world. Even so, 90% of the production of these industries is in the form of coal and oil, which are just the residues of materials produced by green plants in earlier ages. Photosynthesis, then, provides practically all the power, heat and artificial light used by mankind.

As, almost without exception, living organisms that lack chlorophyll use complex organic material for food, they are completely dependent upon green plants, which alone are able to produce this from the inorganic materials, carbon dioxide and water. In addition to the various elements of which it is composed, such food is a source of energy, and when it is broken down this energy is released and becomes available to the organism's tissues. Energy is needed for the growth and the support of the vital metabolic processes; the movement of organisms and the work they do depends upon such an energy supply. The release of energy from foods implies that energy must be put into these organic compounds during their synthesis by plants, and the source of energy used by the plant kingdom is the most obvious one of all—sunlight.

It was soon discovered that water and carbon dioxide are necessary for the reaction, and that the first stable product of photosynthesis is carbohydrate. The basic photosynthetic reaction can thus be written

$$CO_2 + H_2O + \text{energy} \rightarrow \underset{\textit{carbohydrate}}{(CH_2O)} + O_2 \quad \ldots \ (1)$$

whereas the breakdown of food, or respiration, can be considered to be the reverse of this.

This equation agrees with the observed facts that oxygen is produced by green plants in the light, and is absorbed from the atmosphere by organisms when they respire.

Another requirement was soon recognised—the presence of special pigments, of which the two kinds of chlorophyll are the most important. Chlorophyll, which gives plants their characteristic green colour, is normally contained in microscopic bodies, known as *chloroplasts*, and these float about in the cells of the photosynthetic tissue.

An important discovery was made about fifteen years ago by Dr. Robert Hill of Cambridge who showed that aqueous suspensions of chloroplasts separated from their cells were able to produce oxygen upon illumination. However, carbon dioxide took no part in the reaction, but other chemicals were necessary and it was found that these were used as hydrogen acceptors; thus, for example, quinone was converted to hydroquinone. This led to the theory that light was used by chloroplasts to split water to hydrogen and oxygen, the oxygen appearing as a gas and the hydrogen being used to reduce suitable compounds according to the following equation in which X represents the molecule of a hydrogen acceptor:

$$2H_2O + 2X \rightarrow 2H_2X + O_2$$

It is now believed that all the oxygen evolved during photosynthesis comes from water, and this point is indicated by the asterisks in the following modification of equation (1):

$$CO_2 + 2H_2O^* + \text{energy} \rightarrow (CH_2O) + H_2O + O_2^*$$

Perhaps the most interesting aspect of photosynthesis, and one which is being developed the most rapidly, is "the path of carbon". In the above equations only the proportionality of the reaction has been expressed, but as the simplest carbohydrates which accumulate during photosynthesis are the sugars, glucose and fructose, and these each contain six carbon atoms per molecule, the photosynthetic equation becomes

$$6CO_2 + 12H_2O + \text{energy} \rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$$

This polymerisation of carbon dioxide to sugar does not occur in one step but involves many intermediate compounds. At first there was no way of telling which of the vast number of different compounds which occur in plant tissue were these intermediates, and in any case most of them have since been shown to occur in such tiny amounts that it is not surprising that without the present advanced techniques involving radioactive tracers and various types of chromatography their existence was missed entirely. The research groups of Dr. Calvin in California and Dr. Gaffron in Chicago have been pre-eminent in using such techniques for this problem. Carbon dioxide containing radioactive carbon (^{14}C) atoms (which behave *chemically* in the same way as normal carbon atoms) was given to green tissue in sunlight. "Labelled" compounds—i.e. those containing radioactive carbon—that appeared in the tissue were then assumed to be either intermediates or products of photosynthetic reactions. Many of these occurred only in trace amounts but their investigation was made possible by delicate analytical techniques (e.g. paper partition chromatography) capable of dealing with as little as a few millionths of a gram of material or less.

Labelling first occurred in phosphoglyceric acid which is a three-carbon (C_3) compound, but only one of the carbon atoms in the molecule became labelled after very short exposures—lasting only a few seconds—to radioactive carbon dioxide. This indicated that the initial reaction involves C_2 "acceptor" molecules already present in the tissue which add on CO_2 to form an acid (carboxyl) group, according to the following scheme:

$$\text{-C—C-} + {}^{14}CO_2 \rightarrow \text{-C—C—}{}^{14}COOH$$

An exact balance of O and H atoms is not given in this and subsequent equations. Further, it is known that two molecules of phosphoglyceric acid, after certain modifications, will condense together to give a carbohydrate molecule

$$C_3 + C_3 \rightarrow C_6$$

However, it is obvious that there cannot be an unlimited reservoir of the C_2 acceptor molecules. It was found that after several minutes' exposure to radioactive carbon dioxide *all three* of the carbon atoms in the phosphoglyceric acid molecule become labelled, i.e. the acceptor molecule must ultimately be produced from

CO_2. Thus the process appears to be a cyclic one—CO_2 is added to acceptor molecules and although part of the product is converted to carbohydrate some is broken down once more, forming acceptor molecules which take up or "fix" more CO_2. Recently it has been found that it is actually a C_5 compound, ribulose diphosphate, which is the acceptor, but that as soon as CO_2 is added to it it breaks down into two molecules of phosphoglyceric acid, thus

$$C_5+CO_2 \rightarrow 2C_3$$

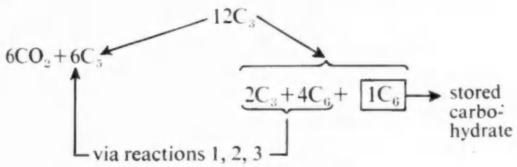
There has been considerable research into the mechanism of the regeneration of the C_5 acceptor, and it has turned out that a complicated series of reactions is involved catalysed by the enzymes transketolase and transaldolase. Starting from one C_3 and two carbohydrate (C_6) molecules, three C_5 acceptor molecules are formed. Thus:

1. A C_6 (carbohydrate) molecule loses two of its carbon atoms which become transferred to a C_3 molecule, the result is one C_4 and one C_5 (acceptor) molecules.

2. Another carbohydrate molecule loses three of its carbon atoms which become transferred to the C_4 molecule that is left over from reaction 1. C_3 and C_7 molecules are thus formed.

3. A C_2 fragment is transferred from the C_7 molecule to the C_3 molecule from reaction 2, resulting in two more C_5 acceptor molecules.

When these quantities are doubled, one sees that six C_5 acceptors are formed from four C_6 and two C_3 molecules. Each C_5 will accept a CO_2 molecule. The result will be twelve C_3 compounds, ten of which will serve to regenerate six more acceptors and two will form a molecule of stored carbohydrate, according to this scheme:



Thus six CO_2 molecules are formed into one carbohydrate molecule, and in the process six more acceptor molecules are formed.

This diagram has given only the carbon balance, but hydrogen and energy have to be supplied as well. Just as CO_2 does not become carbohydrate in one step but needs carrier molecules which transfer it from compound to compound, so hydrogen (derived from the splitting of water) needs carriers too. These are the nucleotide coenzymes, present in the tissue in minute amounts, which are capable of accepting hydrogen and then giving it up to other compounds, such as phosphoglyceric acid. They are, themselves, regenerated to the acceptor form during the process.

By using these various intermediates, coenzymes and enzymes a scientist working in the United States, Dr. Efraim Racker, was recently able to convert CO_2 into carbohydrate in the test-tube.

However, the reactions involving energy are still very obscure. As a source of energy Dr. Racker used adenosine triphosphate (ATP) which is known to be involved in the majority of energy transformations in living tissue. When phosphate molecules are hydrolysed from ATP energy is released and becomes available to the "CO_2 cycle" described above.

The mechanism whereby the photosynthetic pigments are able to absorb light and turn it into chemical energy and whether, indeed, it is ATP which is directly involved here, are topics on which much research is in progress. Recently Dr. Arnon's group in California has reported the test-tube production of ATP when light falls on chloroplasts isolated from plant cells but more work is necessary before we understand this aspect of photosynthesis.

READING LIST

Two of the important papers dealing with recent research in this field are:

Racker, E., "Synthesis of Carbohydrate from Carbon Dioxide and Hydrogen in a Cell-free System", *Nature*, 1955, vol. 175, p. 249.

Arnon, D. I., Allen, M. B. and Whatley, F. R., "Photosynthesis by Isolated Chloroplasts", *Nature*, 1954, vol. 174, p. 394.

Review articles on recent research progress are to be found in *Annual Reviews of Plant Physiology*.

The following books will be found useful:

Hill, R. and Whittingham, C. P., *Photosynthesis*, 1955; this is a Methuen Monograph.

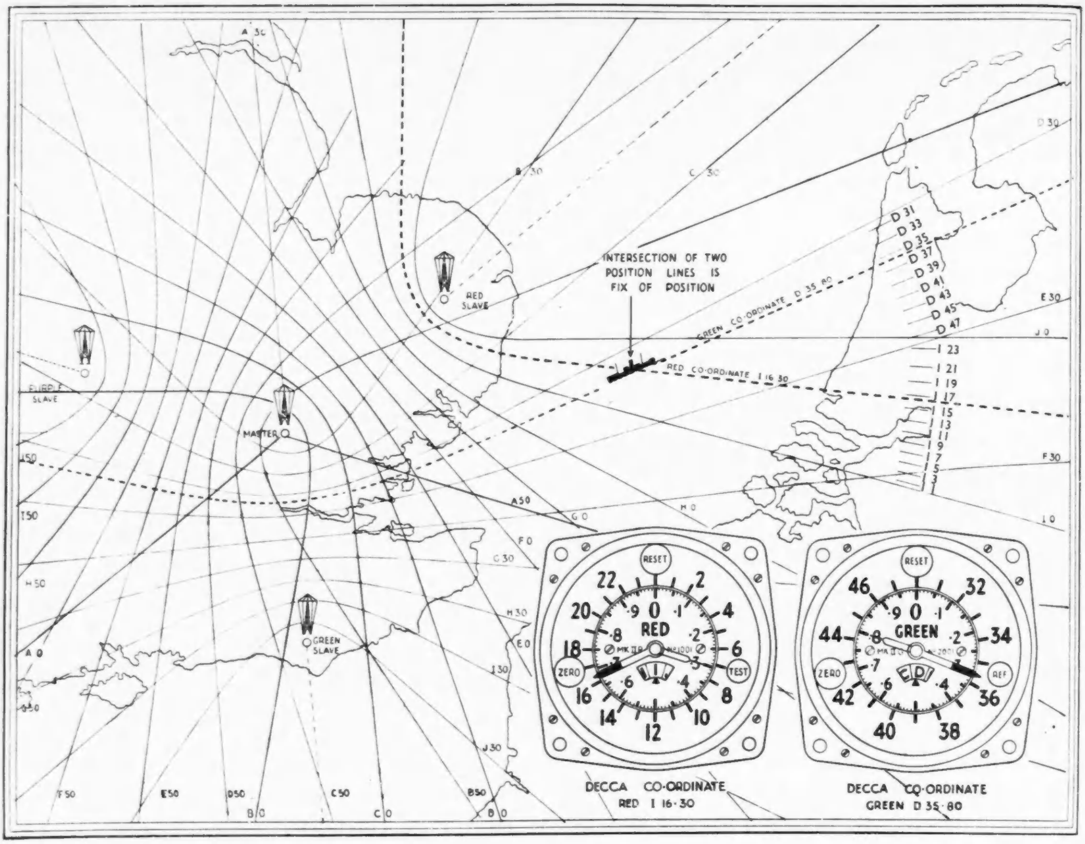
Rabinowitch, E. I., *Photosynthesis*, an authoritative work in three parts, of which two have so far been published (1945 and 1951). (Interscience.)

A RADIO-AID TO NAVIGATION

The Swedish Government's recent decision to establish a chain of Decca Navigator stations is further evidence of the growing appreciation of this British-developed radio position-fixing aid to navigation. Well over a million square miles of Western Europe are now covered, and more than 2600 ships and aircraft are equipped to use the system—they include the largest Atlantic liners at one end of the scale and small trawlers at the other. Decca is extensively fitted in ships of the Royal Navy and the navies of eight other countries.

An important reason for the wide acceptance of the system is that it meets the requirements of the International Marine Conference on Radio Aids to Navigation for accurate position-finding. Under the worst possible conditions, and at sea-level, each chain of stations covers an area within a radius of about 240 nautical miles, and at that range the greatest positional error is 5 miles. Under the best conditions an accuracy of 50 yards at 100 miles is achieved.

The Decca system has as its basis a series of "chains" of long-wave radio transmitting stations. Each chain comprises four ground stations: a central "master" with three outlying "slaves" disposed in a star pattern some 80 to 100 miles in radius. The stations radiate continuous radio transmissions which interact to form a stationary radio pattern, akin to the stationary wave pattern which can be formed on the surface of water by the intermingling "rings" from two stones dropped in side by side. The lines making up this pattern remain

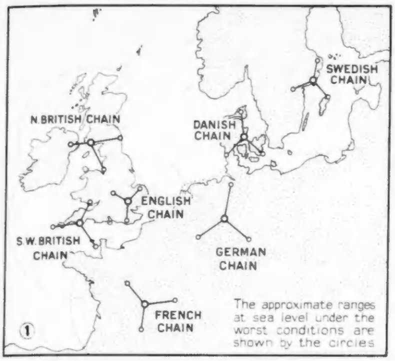


Layout of the English Decca Navigator Chain, showing approximate sites of the master station and three slave stations: these are simultaneously radiating continuous-wave radio transmissions which interact to form a stationary wave pattern. Three families of hyperbolae are involved in this pattern, which remains in the same position, and can thus be depicted on standard charts for use as a system of navigational position lines. Taking one family of hyperbolae (e.g. between master and red slave), then for any spot of any particular hyperbola the difference in the distances of that point from the two stations is constant. A measure of that difference is the difference in the times the radio transmissions from the two stations take to reach the spot. This is the basis of "Decca-navigation". A reading on the dial depends on that time difference, and from the reading one knows that the ship's position lies somewhere along a particular hyperbola; thus from the red dial one gets a "red" hyperbolic coordinate; similarly with the green dial. The two appropriate hyperbolic position lines corresponding to the dial readings are found on the chart and the ship's position is where they intersect.

permanently in known positions and can thus serve as navigational position lines. They are depicted on standard marine charts as intersecting lattices, each line being numbered distinctively.

The Decca position lines are not bearings, nor do they form radio "beams"; they are lines of constant distance-difference with respect to the appropriate pair of stations—the "master" and the "slave"—producing them. In a ship the signals are received by the Decca Navigator equipment, the first section of which is a radio receiver, and a comparison is made of the times taken by the master and slave signals to reach it. Since radio waves are assumed to travel at a constant speed, the time differences correspond to distance-differences and the equipment indicates which position line the ship is on in each pattern. The information is displayed continuously by three dials labelled red, green and purple, whose readings correspond with the numbering of the charted position lines. All the mariner has to do to fix his position is to read two of the dials and to find on his chart the intersection point of the two position lines bearing the numbers indicated. The choice of any two of the three dials will depend upon which of them gives the best angle of cut in the particular area. For special purposes a "track plotter" can be used. This equipment, which integrates the time-difference information, incorporates a "crab" carrying a pen which moves over a chart and inscribes the precise track position continuously.

In aircraft the Decca Flight Log responds directly to the invisible grid set up by the same set of radio stations, just as the marine track-plotter does, dispensing with the process of transferring readings to a chart and automatically tracing the track of the aircraft across a



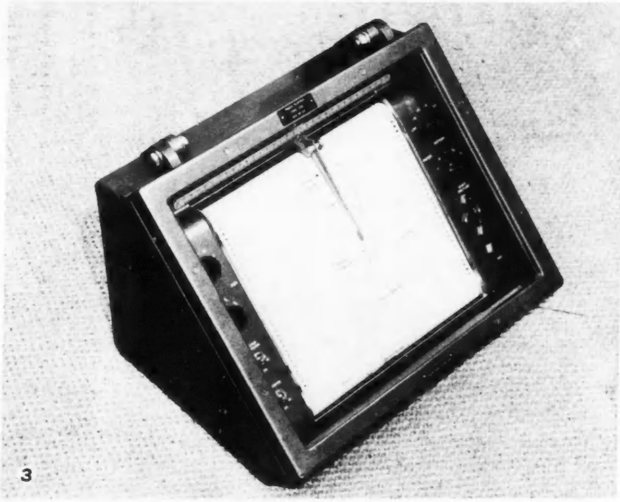


FIG. 1. About 1½ million square miles of Western Europe are already covered by this radio-fixing system. The Swedish chain is due to be operating in 1956. FIG. 2. An officer reads the dials and obtains a "fix" by finding where the two position lines intersect on the chart. FIG. 3. The Decca Track Plotter, a recent development, automatically traces the course of the ship on a chart, and does for marine navigation what the Decca Flight Log achieves for aerial navigation.

map. By this means the pilot can see at a glance, and with no manipulation, his position and course to steer.

The map shows the existing Decca coverage in Europe, including the projected chain based on Stockholm which will be in full use by 1956. These give continuous position information for ships and aircraft from the Bay of Biscay to the Baltic Sea, and over the major part of Western Europe. The system is expected to be extended soon by a chain in the south of France covering the Mediterranean area, and by another network of stations based in the Orkney, Shetland and Faroe area. Spain and Italy are also discussing the provision of such coverage, and plans for setting up chains in India are almost completed. This type of navigational equipment is being manufactured under licence in the United States, an achievement indeed for this British radio development.

Obviously the Decca Navigator system is a medium-range aid, and it provides "lane identification" for ships and aircraft coming into range from outside or when passing from one chain to the area covered by another chain. Where no long-range aid is available, astro-navigation must be employed; it provides only limited accuracy and effectively restricts position-finding to the dark hours. The introduction of jet aircraft with the economic necessity of operating at heights for which meteorological conditions, particularly in the matter of wind-speed and direction, are still largely unpredictable emphasises the existing difficulties on long-range flights and results in a far more pressing need for an accurate long-range navigational aid.

To meet this need two new navigational systems, largely based on Decca techniques, were discussed at last year's session of the Communications Division of the International Civil Aviation Organisation in Montreal.

Encouragement was given for their development and evaluation. One of these aids, known as *Delrac*, is designed to provide coverage over a very wide area; the other, called *Dectra*, is a position-fixing system intended for a specific route such as a long ocean crossing. Essentially Dectra consists of two master-slave pairs of transmitting stations, one at each end of the route to be covered, and, in each aircraft, a receiver resembling the normal Decca airborne set. Each pair of terminal stations provides a hyperbolic pattern giving a tracking facility, while a ranging pattern along the route is produced by a station at one end acting as master and one at the other end as a slave. It is intended to operate over stage lengths up to about 2000 miles and to provide a minimum tracking accuracy of plus or minus 5 nautical miles and a ranging accuracy better than 10 miles over the entire range—a performance not so far approached by any other navigational system. As the route terminals are approached and the "lanes" of the tracking patterns taper down to their minimum width of a few hundred yards, accuracy increases correspondingly.

The Ministry of Transport and Civil Aviation and the Ministry of Supply have been investigating Dectra with a view to a possible trial of the system across the Atlantic.

EINSTEIN: A TRIBUTE

PROF. E. N. DA C. ANDRADE, F.R.S.

The name of Einstein will always live as one of the great originators in science, one of the few who started something fundamentally new, one of those of whom it may be said that, in his field, nothing was quite the same after his work. He made many great advances in physics, but everybody, quite rightly, connects his name with the theory of relativity, which deals with the fundamental way in which space and time are connected. Perhaps I may select one simple point in a subject where there is not much that is simple.

Einstein pointed out that, if people in two different systems moving *relatively* to one another—the earth and Mercury, if you will—are to set their watches a signal must be sent from one to the other, and that the speed of this signal comes into the whole question of the mechanics of the universe, that it is a fundamental quantity for all space-time relations. All signals that can be sent through space—light or other electromagnetic waves, such as "wireless"—travel with the same speed, the speed of light. Since Einstein, the speed of light comes into all fundamental questions of physics: it has been elevated to supreme importance.

One profound consequence that Einstein drew from his work on relativity was that mass and energy were interchangeable—one can disappear if it is replaced by a precise equivalent quantity of the other. The velocity of light comes in here, for the equivalent energy, in the proper units, equals the mass multiplied by the square of the velocity of light, which is a prodigiously large number. If I could make this sixpence disappear suddenly, the energy appearing in its place would destroy the whole of this district. That is the principle of the atomic bomb: the nuclear transformations involved lead to a disappearance of mass and the appearance, in its place, of a formidable amount of energy. It is an irony of fate that Einstein, always an ardent and vocal champion of peace and international accord, should have his name so prominently associated with this terrible engine of destruction. In 1939 he wrote to Roosevelt, saying: "A single bomb of this type, exploded in a port, might well destroy the whole port, together with the surrounding territory." In 1950 he drew a terrifying picture of the possibilities of the H-bomb.

The makers of the physics of today may be said to be Planck, Rutherford, Einstein and Niels Bohr. Niels Bohr, the youngest, is happily still with us and in full vigour. I would not like to prophesy which will appear the greatest to the historian of the future, if he discusses such a question. In any case, we salute the passing of a giant, whose first fundamental paper on relativity, the basis of the whole structure, appeared just fifty years ago.

EINSTEIN: A BIOGRAPHICAL SKETCH

CHAPMAN PINCHER

With the death of Albert Einstein on April 18, a small blackboard in a Manchester University laboratory becomes one of the historical treasures of the nation. The mathematical symbols chalked on the board by Einstein years ago and now preserved under a layer of varnish are mummified thoughts from one of the most penetrating human minds of all time.

Most people picture Einstein as a meek, long-haired man who wore sweaters too big for him and spoke with a "musical comedy" accent on subjects remote from everyday life. In reality he was a revolutionary whose daring ideas have changed the lives of ordinary people as forcibly as those of Karl Marx.

Einstein did much more to make the atomic bomb possible than start up the chain of arm-chair thought which led to the release of the atom's energy. The explosion over Hiroshima and its political consequences were directly due to a letter which Einstein sent to President Roosevelt urging him to set science working on an atomic bomb lest the Nazis gain the mastery by producing that trump-card before Britain or the U.S.A.

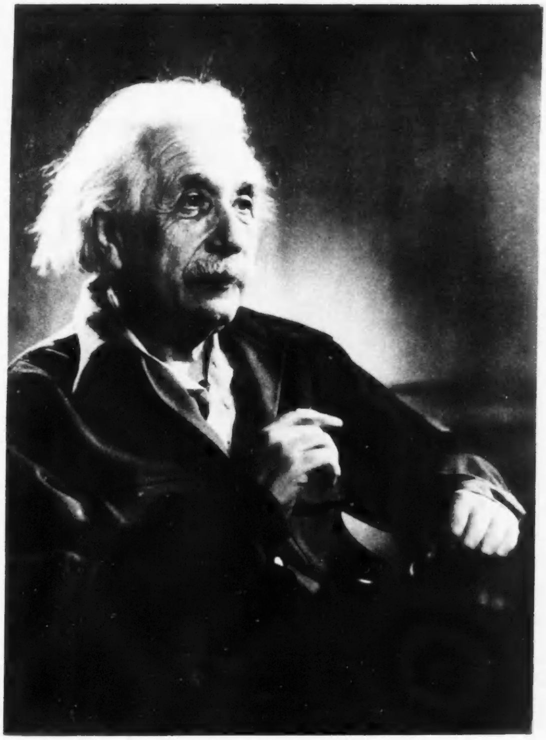
His restless mind entirely reshaped the scientific laws on which our civilisation is based. It gave us new concepts of time, space, gravity and the universe.

Einstein was born of Jewish parents at Ulm in Germany in 1879. As a baby he was so slow in learning to talk that his mother thought he was mentally backward. His education was hampered by the frequent business moves of his family between Germany, Italy and Switzerland, moves due mainly to the fact that his father was a failure, first as an electrician, then as a merchant.

At twelve Einstein was already fascinated by mathematics, but he was not in any way a prodigy. At sixteen he failed his first important examination—for the famous Zurich Polytechnic—mainly due to his deficiencies in languages, but he was successful the next year. After graduating there, he became a Swiss citizen in 1901.

Einstein used his technical training to get a job in the Berne Patent Office, but during his seven years there he was more interested in his own ideas than those of other inventors. He worked out many of his most abstruse ideas during office hours, scribbling on scraps of paper which he hid hurriedly when a supervisor appeared.

In 1905 when he was twenty-six years old Einstein declared that the theory that light travels in waves is wrong. Light travels in a series of separate "bullets"—or *photons*, to give them their scientific name, he



Albert Einstein (1879–1955). A camera portrait by Karsh of Ottowa.

claimed. The "bullets" given off by a candle-flame, by the sun or any other source of light follow each other so quickly that the eye cannot detect their separate nature. These bullets have weight, Einstein declared, so in theory sunshine could be weighed. The idea seemed ridiculous but his mathematical proof was unshakeable and explained so many odd facts that the first law he based on this work—the Photoelectric Law—eventually won him the Nobel Prize.

At first it did not seem that his theories could ever be tested, but the genius of the scientist who never carried out any experiments solved the difficulty. Einstein realised that if light has weight a ray of starlight passing close to the sun on its way to the earth should be bent by the sun's gravitational pull. He boldly predicted that this would happen and stated the exact amount by which the light ray would be bent. This prediction, on which Einstein staked his reputation, was fulfilled during an eclipse in 1919, and has since been confirmed by more accurate measurements. Einstein calculated that the sun should displace a starlight ray grazing it by 1·75 seconds of arc: the latest observed displacement was 1·70 seconds of arc. Only a mind working on the grandest scale could have thought up an experiment which virtually turned the universe into a laboratory.

Einstein followed up with a statement that whereas the speed of a gun bullet can be increased by firing it from a fast-moving body like an aeroplane, the speed of light-bullets cannot possibly be altered in this way. The speed of light through empty space is one of the unalterable constants of the universe, he claimed. In other words if a light beam were switched on from the front of a rocket travelling at 10,000 miles per hour the beam would travel no faster than a light shone from the ground.

This idea contradicted what was then regarded as common sense but Einstein quickly showed that much of common sense is an illusion.

He proved in his Special Theory of Relativity—first published in 1905—that space and time cannot be considered as separate quantities but are really so closely related that one should only speak of space-time. All measurements of time like the intervals marked out by the hands of a clock or a shadow moving round a sun-dial are really measurements of space.

Einstein realised that there is no universal "Now". He saw that the assumption of an absolute time in Newton's reasoning was a flaw. It is impossible to compare the time in two different places without sending a signal between them and that takes time. Because of the time light takes to travel every moving object has two positions—where we see it and where it is. Events which appear in one order to one observer may appear in a different order to another, which upsets the idea that cause must precede effect.

Though Einstein built his theories on the ideas of previous thinkers to some extent, he was the first to show clearly that all movement is relative. This is most simply understood by imagining every object in the universe to be removed except one. Then there would be no means whatsoever of knowing whether that object was at rest or hurtling through space. As another scientist has put it: "This is no hitching-post in the universe."

Furthermore, space has no existence of its own, Einstein argued. If all the objects in space could be removed space itself would disappear. Time too has no separate existence since it is only a measurement of the order of events. Without those events there is no time.

By carefully reasoned argument Einstein went on to prove that matter and energy are just different forms of the same thing. One can be converted into the other and both have weight.

He expressed this idea in the simple law $E=mc^2$, which means: Matter can be converted into energy at such a rate that the amount of energy, in ergs, produced by the disappearance of a given mass is equal to the mass in grams multiplied by the square of the velocity of light (measured in centimetres per second). This simple piece of scientific shorthand explained for the first time why the sun has gone on shining for so long, and why substances like radium can keep giving off energy.

It is not possible to prove that a cricket ball increases in weight when it is thrown because the increase at low speeds is so small, but scientists were not long in proving that certain small particles thrown out by radium increase their weight during their phenomenally fast flight.

This happy camera study of Einstein (seen with the Prime Minister of Israel, David Ben-Gurion) was taken in 1951. Readers will recall that on one occasion Einstein was invited to become Israel's president.

In 1932 the atom-smashing experiments of Cockcroft and Walton at Cambridge proved the accuracy of Einstein's equation. Later Hiroshima blasted it into the public mind.

After his early achievements Zurich scientists tried to get Einstein a job in the university there, but his lecturing was so bad that he had to be appointed professor "extraordinary" which gave him most of his time free for research. Einstein gained prestige but lost money over this appointment, so his wife had to take in lodgers. As Einstein put it "In my relativity theory I set up a clock at every point in space but I found it difficult to provide even one clock for my room".

In the next twelve years he poured forth a succession of revolutionary ideas. In 1910 he became professor of theoretical physics in Prague. He left in 1912 to return to Zurich as professor of theoretical physics.

Just before the First World War, when fully established as an academic scientist Einstein moved to Berlin where he became director of the Kaiser Wilhelm Institute.

Between 1915 and 1920 Einstein published his General Theory of Relativity—a triumph of human reasoning. It gave a much more satisfying explanation of gravity than Newton's "falling apple" theory, for it did away with the necessity for a mysterious force called gravity acting at the centre of the earth. The apple falls because that is the only path it can take in space, said Einstein. The path of the apple has nothing to do with the earth. It is a property of space. Things take a curved path because space itself is curved. This idea can easily be followed by imagining a boy playing marbles on rough ground. To a man watching from a high window the marbles might appear to curve away from the straight path because they are pulled by some invisible force. But a man on the ground would see that the real reason was the curvature of the ground over which the marbles were travelling. Newton saw the first picture; Einstein saw the second, and so approached closer to the heart of the problem.

Einstein's theories gave rise to a new conception of the size and shape of the universe. Astronomers now picture it as a huge balloon with billions of inelastic patches stuck to it. The patches represent the stars, planets, moons, comets and other heavenly bodies. The skin of the balloon represents curved space or more accurately curved "space-time". The balloon is increasing in size and the patches are getting farther away from each other because the universe is rapidly expanding.

In 1920 Einstein resumed German citizenship. Always an uncompromising enemy of Hitler, he had to leave Germany to escape persecution and eventually he went to live in Belgium where the government was so concerned for his safety that it provided him with two bodyguards. When the Nazis listed him an enemy of

the Reich he became the symbol of all who were persecuted. Finally he took up a professorship at the Institute of Advanced Study in Princeton—a post from which he retired in 1945.

For thirty years Einstein had been trying to build up one theory which would harmonise all forms of motion from the movements of the biggest stars to the whirling flight of the electrons inside atoms. This Unified Field Theory which he put forward in a tentative way in 1950 attempts to unify the laws of gravity and the laws of electro-magnetism in one great cosmic law. Einstein was never able to think up any way of testing his last theory, and many scientists believe that it is unsound.

When the Archbishop of Canterbury once asked Einstein what effects his relativity theory would have on religion he answered "None". This time Einstein was wrong. His ideas have given new strength to religion, shaking the foundations of fatalism and materialism.

The trend of thought begun by Einstein has shown that men can never get to close grips with reality because the more they dissect the stuff the world and they themselves are made of the more elusive it becomes. It proved that the future is governed by the laws of chance and therefore cannot be predicted except within the limits of uncertainty. In science the word "always" has come to mean "more often than not".

Here we encounter the paradoxical situation that Einstein, esteemed as the revolutionary innovator, resisted some innovations of quantum theory such as Heisenberg's uncertainty principle, as Bertrand Russell explained in his broadcast appreciation of Einstein (see *The Listener*, April 28, 1955).

Such was this exceptional man's nature that he could never entirely accept the implications of his own discoveries. "I just cannot believe that God plays dice with the universe," he said. Einstein did believe in God—though not the God of any orthodox faith. "My religion consists of a humble admiration of the superior spirit who reveals Himself in the slight details we are able to perceive with our frail and feeble minds," he wrote.

Einstein consistently spoke out for human freedom and he urged all American intellectuals to refuse to give

Einstein speaking at the famous Albert Hall meeting of October 3, 1933, when the appeal fund of the Academic Assistance Council was opened to raise money for scholars forced to leave Germany by the Nazis. On the right of the photograph are seen Lord Rutherford (president of the Academic Assistance Council, which later became the Society for the Protection of Learning) and Sir Austen Chamberlain.

evidence before the "inquisition" of investigating committees. After Hiroshima and Nagasaki, he tried to rouse world opinion to prevent the use of atomic weapons, sometimes unwittingly lending his name to organisations with dubious political purposes. He was responsible for the now famous *mot*: "If World War III is fought with atom-armed missiles, then World War IV will be fought with clubs."

A tremendous worker throughout his life, Einstein's only relaxation apart from reading and occasional yachting trips was playing the violin at which he was sufficiently competent to accompany the pianist Artur Schnabel. The mathematical master of space and time had difficulty in keeping to the time of a musical rhythm resulting in the delightful moment when Schnabel stopped playing abruptly and rasped "Can't you count, Albert, can't you count".

Einstein died on April 18 after a short illness due to gall-bladder trouble. He was seventy-six.

Prof. Andrade's tribute to Einstein is the gist of the television talk which he gave on the day after Einstein's death, and which reached more people in Britain than any other appreciation or obituary at that time when no national newspapers were being printed.

EINSTEIN'S BOOKS

The following is a list of Einstein's works published in book form:

Relativity (English translation), 1920.
Zur Einheitlichen Feldtheorie, 1929.
About Zionism (English translation), 1930.
(with Sigmund Freud) *Why War?* (English translation), 1933; *My Philosophy*, 1934; *The World as I See It* (English translation), 1935; *The Evolution of Physics* (with Leopold Infeld), 1938.

The Unified Field Theory is described in the fourth edition of Einstein's book, *The Meaning of Relativity* (published in Britain by Methuen in 1950).

A miscellany of his writing since 1936 on such various topics as Zionism and Peace was published in Britain in book form under the title *Out of My Later Years* (Thames & Hudson, 1950).

RELATIVITY: A READING LIST

In response to readers' requests for a reading list on this subject, we recommend the following as being books that provide good, simplified explanations of relativity.

Einstein and Infeld, *The Evolution of Physics* (C.U.P.).
Einstein, *The Meaning of Relativity* (Methuen); requiring a fair mathematic knowledge.
Eddington, *Space, Time and Gravitation: An Outline of the General Relativity Theory* (C.U.P.). Published in 1920, but still valuable.
Eddington, *The Nature of the Physical World*. (One chapter on relativity and repeated references.)
James Jeans, *Physics and Philosophy* (C.U.P.).

THE RAW MATERIALS OF ATOMIC POWER

C. F. DAVIDSON, O.B.E., D.Sc.

Chief Geologist, Atomic Energy Division, H.M. Geological Survey

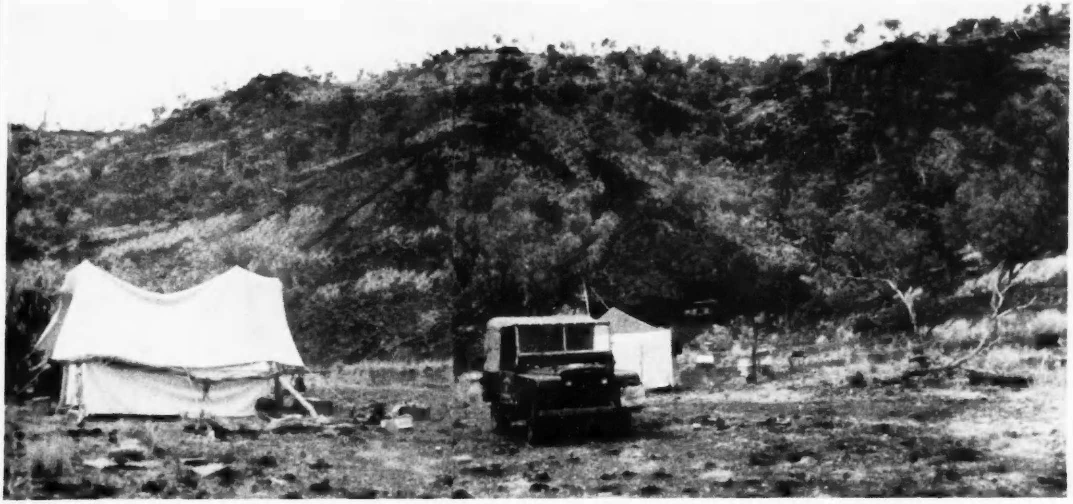
Two books have recently appeared which are of importance to the many authorities interested in the search for radioactive ore deposits. Minerals for Atomic Energy *by R. D. Nininger (Macmillan & Co., 1954, 367 pp., 55s.) is an authoritative text on explorations for these ores in the field, and* Nuclear Geology *edited by H. Faul (Chapman & Hall, 1954, 414 pp., 56s.) deals mainly with laboratory techniques for the study of radioactive minerals. In this article Dr. Davidson reviews these works and speculates on the extent of world resources of the fissile elements. Dr. Davidson is head of the Atomic Energy Division of the Geological Survey, who are the geological consultants to the U.K. Atomic Energy Authority responsible for appraising ores from which the Authority may draw its raw materials.*

According to the recent White Paper entitled *A Programme of Nuclear Power* (Cmd. 5389, February 1955), the British Government "consider that enough uranium will be available for the civil programme over the next ten years, after making the best assessment possible of world supplies and of world requirements for all purposes". This announcement is a striking testimony to the success of the search for new deposits of uranium ore in which geologists have been intensively engaged for the last decade. But it certainly does not mean that the need for further prospecting has come to an end. Ten years from now, if politicians can save the world from atomic chaos, the prodigious powers of nuclear energy will be harnessed in many countries to work for the welfare of mankind. The United States Atomic Energy Commission has recently calculated that by 1975 the nuclear power industry of the free world will require about 17,000 tons of uranium oxide annually, in order to supply new reactors likely to have been built by that date; but this estimate takes no account of the possibility that nuclear installations may replace existing steam plants based on high-cost coal. A requirement of this order, at a guess, is close on twice the total present-day production. The geologist cannot therefore rest on his laurels; and the prospector can remain assured that the discovery of a major uranium ore body will long be one of the greatest prizes of his precarious profession.

These two books will do much to further explorations for the raw materials of atomic power. They are by far the most noteworthy of several publications on the same topic which have appeared in recent years; but they are complementary in that they are entirely dissimilar in approach and are directed to quite different readers. Dr. Nininger's work meets the current needs of the prospector, the field geologist, the company executive, and the inquiring politician. Dr. Faul has edited a symposium of papers by different authors—twenty-one American, two British, two Swedish and one Canadian—to provide a scientific text which summarises our newest knowledge deriving from the academic investigation of natural radioactivity. For the immediate future the former work is of the more practical value, but the latter volume contains the seeds from which long-term economic studies are likely to germinate.

Dr. Nininger, who is now Assistant Director for Exploration in the U.S. Atomic Energy Commission's Division of Raw Materials, has been associated with the atomic energy project since its earliest days, and he draws widely upon personal experience of work in many countries. His book is in three parts, with appendices: first, a description of the principal ore minerals of uranium, thorium and beryllium, with an account of the main deposits; second, an evaluation of the possibilities of making useful discoveries in various parts of the world; and third, a review of the various prospecting methods in common use. The appendices, culled from official publications, include tables designed to aid mineralogical identifications, particulars of the laws and regulations relating to prospecting in the United States and the British Commonwealth, and schedules giving the minimum prices for ores and concentrates guaranteed by these countries. The work is extensively illustrated, but apart from two fine coloured plates of uranium minerals reproduced from the *National Geographic Magazine* the quality of the illustrations could be greatly improved. The inclusion of particulars of discoveries made in the 1954 prospecting season gives evidence of the speed with which the book has been produced, and as a consequence some minor errors are inevitable; but that these do not detract from the usefulness of the work is seen in the need for three printings, totalling 15,000 copies, in the last four months of 1954. Seldom has a scientific primer met with such an immediate demand.

Unfortunately the fundamental thesis adopted by Dr. Nininger in assessing the potentialities of unexplored areas of the earth's surface is of doubtful validity. He suggests that "the most important primary vein deposits of uranium, those responsible for the greatest production in the past as well as the several promising producers" are all situated along the borders of the stable continental blocks known as shields; and he postulates that exploration along the shield margins will be more profitable than elsewhere. It is true that many of the known pitchblende veins and uranium-bearing pegmatites, other than the deposits in late granite massifs like those of Cornwall or the Central European Erzgebirge, do occur close to the margins of the continental shields; but there is every reason to suppose that this pattern of distribution, for which there is no geological explanation, is due solely to the relatively intense exploration that the more accessible marginal areas have received. The apparent absence of mineral lodes in central Australia, in the hinterland of Africa or in the interior of Brazil may well be occasioned by the difficulties of making an adequate search for them. This thesis rather



MARY KATHLEEN PROSPECT, QUEENSLAND. This hill-side of uranium ore was discovered during week-end prospecting by a local taxi-driver, who sold part of his rights for £A250,000. Work to assess the deposit is now in progress. This prospect is rich in ores of the rare earths. (*Photo, C. B. Campbell.*)

resembles the assumption, widespread in the 17th and 18th centuries, that gold is only found near the Equator. The belief of the Spaniards in this hypothesis facilitated the cession to Captain Vancouver, in 1790, of their sovereign rights in America north of the Gulf of California. Today, in regions where geological knowledge is scanty, it is still dangerous to assume other than that uranium, like gold, is where you find it.

It is also very doubtful whether deposits in true mineral lodes will, as is commonly assumed, furnish the uranium resources of the future. A century ago Cornwall was the greatest copper producer in the world, the ore being mined from narrow veins which yielded material capable of being concentrated manually or mechanically to high-grade mineral suitable for smelting; but seventy years later, following the discovery of the great low-grade porphyry coppers of America and the copper shales of Rhodesia, scarcely one of the Cornish deposits would have been workable at a profit had it been left virgin. The trend from small high-grade to vast lower-grade deposits did not occur, as commonly supposed, because all high-grade ores were exhausted, but because the lower-grade mineralisation was capable of being worked in immense tonnages, using new chemical-metallurgical processes, to give a much cheaper end-product. With uranium a somewhat similar change has taken place within a decade. The great potentiality for future uranium production does not lie in high-grade pitchblende lodes supporting small mines, but in great bodies of lower-grade ore readily capable of being exploited on a grand scale. Typical of occurrences of this kind are the gold mines of the Witwatersrand, which yielded about £14 million of by-product uranium in 1954, and which may double this output in 1955. Rather similar ore deposits were found in 1953–4 at Blind River in Ontario: this is popularly spoken of as a "billion-dollar field", and by next year it will have the two largest uranium mills in the world, each treating 3000 tons of ore daily. In much the same category are some of the mines of the Congo-Rhodesian Copperbelt and of Rum Jungle in Australia, where uranium is found associated with copper and cobalt.

In these newer discoveries the uranium and associated mineralisation is rather widely and evenly distributed throughout sedimentary strata such as conglomerates or shales, instead of being concentrated into small but rich veins and pockets such as were worked in the older mines; and the origin of these so-called "disseminated" ores is one of the most hotly debated problems of economic geology. One school of thought holds that the ores were deposited contemporaneously with the sediments in which they are found, either as detrital minerals, as chemical precipitates, or through bacterial action on the floors of ancient seas; whilst the opposition maintains that the mineralisation has been introduced by fluid emanations from later granitic intrusions. The determination of the absolute ages of the ores (by isotopic analyses conducted in the mass spectrograph) gives strong support to the latter school. For example, lenses of copper-uranium ore dispersed throughout the Triassic-Jurassic sandstones and limestones of the Colorado Plateau in America have, by these techniques, been found to be of early Tertiary age, coeval with pitchblende veins and granitic intrusions cutting the strata nearby. Again, the mineralisation of the Congo-Rhodesian Copperbelt is dated at 612 $\pm$ 10 million years (late pre-Cambrian), in exact agreement with the age of granitic activity in Tanganyika to the east; and the gold-uranium ores of the Witwatersrand are just over 2000 million years old, contemporary with early

The "billion dollar" field at Blind River. (*Left*) A winter view of part of what may prove to be the world's largest uranium field; over 15,000 prospectors have staked claims. The ore occurs as conglomerate reefs resembling the great gold-uranium formation of the Witwatersrand. (*Right*) The mining camp at Quirke Lake, which will feed one of two 3000-ton mills in the Blind River region by 1956.

pre-Cambrian granites along the Rhodesian-South African border. It is possible that before long age-data of this kind will have a profound influence on prospecting programmes, since such knowledge circumscribes the geological province in which ores are likely to occur. The methods by which such determinations are executed are many, but they depend principally upon the radioactive decay of the uranium isotopes and of thorium to isotopes of lead, of rubidium 87 to radiogenic strontium 87, and of potassium 40 to argon 40. Dr. Faul's text includes important contributions summarising the techniques in common use, and he lists some 350 age-determinations carried out in recent years on minerals from many parts of the world.

Of every thousand uranium discoveries reported by prospectors a hundred may merit some surface pitting and trenching, ten may be worth further exploration by diamond drilling and underground mining, and one may repay handsomely the money sunk in development. The field geologist, whose duty it is to appraise these finds, approaches his work rather like the general practitioner in medicine. Ore deposits are abnormalities in the earth's body; and the presence and nature of the abnormalities has to be assessed from surface symptoms that are often complicated and obscure. The "rock doctor" attains Harley Street status only if he has a well-developed clinical sense—though a good "bedside manner" is a useful attribute in dealing with boards of directors! But the general practitioner in geology, like his medical colleague, must now have behind him an elaborate organisation of laboratory services; and it is to these services that Dr. Faul's symposium gives most attention. The value of mass spectrometry has been referred to above. Autoradiography, whereby the distribution of the radioactive phases in a suspected ore may be discerned by exposing a specimen to special photographic plates, helps in the identification of the uranium and thorium minerals present. Radiometric methods of analysis are quicker and cheaper than chemical essays in proving the grade of ore samples, and in showing whether the radioactivity is due to uranium, to thorium, or to a disproportionate excess of the daughter elements into which these metals decay. Sometimes the laboratory technician may come to the aid of the geologist in the field, to lower Geiger counters or scintillometers down drill-holes and so map out the precise horizons where the mineralisation occurs, or to carry out explorations by other geophysical methods. *Nuclear Geology* performs a useful service in demonstrating how wide a range of expertise is available, and indeed is necessary, for the comprehensive study of a radioactive ore body.

Ten years ago doubts were expressed in some quarters whether uranium supplies would prove adequate to meet atomic programmes. Today uranium plays an economic part in the mining industry of the world that is only surpassed by the mineral fuels, by gold, and by the common industrial metals. The frequency with which new finds of major importance are being made gives little ground for fear of future shortages. Confidence that there will be a great rise in demand as nuclear power plants come into being and as conventional fuels are replaced by fissile elements should perhaps be tempered with caution, for there is still uncertainty on the extent to which thorium, a cheaper metal than present-day uranium and one which is likely to be found in at least equal abundance, will find a place in the nuclear reactors of the future. Again, the distant future may see a marked improvement in the efficiency with which fissile materials become "burned up", giving a greater yield of power per unit of metal. In ten years, too, the high capital costs of the many mining and concentration plants now in existence will have been amortised, giving hope of a cheaper output. The task of the prospector and geologist of the future is thus a much more difficult one than it has been in the past. Not only must he find uranium—he must find cheap uranium. Given an era of peace, there is no reason to suppose that uranium mining will become other than a highly competitive industry, regulated by economic considerations as closely as is the production of other mineral commodities.

THE COYPU

R. A. DAVIS, M.Sc., D.I.C., A.R.C.S.

Sometimes when one visits a circus or travelling fair, one of the sideshows is billed as "the biggest rat in the world", with a lurid description of how the animal was "caught in a sewer", or in even more "horror-comic" circumstances. Its great size is then attributed to the abundant and ghastly nature of its food-supply.

The creature exhibited is usually a specimen of the Coypu or nutria (*Myocastor coypus* Mol.) an aquatic rodent of the porcupine or Hystricomorph group (*Hystrix* is the porcupine genus), although it has no spines. The coypu is in this group, although it does not look like a porcupine in external features at all. This mammal is native to South America, where there are said to be three sub-species, inhabiting streams, swamps, lakes and tidal waters of the coasts. The animal is very markedly aquatic, having webbed hind-feet, and the remarkable feature in the female is the dorsally-situated mammae, which enable the young to feed while the mother is in the water. Its large orange-coloured incisor teeth give the animal a fearsome and rat-like appearance, and its size alone makes it impressive. Adults may range up to about 20 lb. in weight, though most are much less than this, 10–15 lb. being a good weight for a fair-sized specimen.

This rather ugly rodent has a coat of short thick brownish rather silky fur, with a thin outer coat of long coarse hairs. The fur is the "nutria" of commerce, and is the reason why this strange animal is now well-established in the wild state in our own East Anglian country-side.

It has been bred in Europe on fur farms since the 1880's, and was introduced to Britain about 1930. By the beginning of the Second World War, over forty nutria fur farms had been started here. During the war, nutria-farming was abandoned. It might be thought that it was then that the important escapes took place, but in fact the sporadic occurrence of a few wild coypus has been reported a number of times over the last twenty years, and some of the escapes undoubtedly took place before 1939. However, the exact causes of the coypu becoming an addition to our fauna are mainly of historical interest, as it is now a firm feature of the East Anglian scene.

Apart from its rather frightening appearance, are there any reasons for objecting to the establishment of the nutria? Biologists tend towards caution, and are well aware that the introduction of any new animal to an unfamiliar environment may be fraught with danger. The instances of the rabbit in Australia, the grey squirrel in Britain, the mongoose in the West Indies, and the musk-rat in Europe, may be quoted as examples of what can happen. The introduction of the coypu has not so far given rise to alarm. What of its habits in South America, and in other countries to which it has been introduced? What it does in Britain is also of interest, as is also the attitude of the human population to the newcomer.

Coypus are vegetarian, but on the coasts of S. America they are known also to eat molluscs found on the shore. At present there are no records of them doing

Typical damage done by coypus in Wheat Fen. The floating debris consists of reedmace (*Typha*) pulled up by these animals. (*Crown Copyright Reserved.*)

this in Britain, but there is no reason why they should not if they were to become numerous in estuaries. They have been recorded as an agricultural pest in Argentina, and as a minor pest of cabbages in riverside vegetable gardens in the Pacific north-west of the United States. In the south of the U.S.S.R., in Western Georgia, the coypu was apparently deliberately introduced, and in 1941 a review of the situation there was published in Russian. It was then recorded that it fed mainly on herbaceous water-plants, particularly the tender parts of leaves and stems near the roots of such plants as species of reed-mace (*Typha*) and sedges such as *Cladium mariscus*. They thus levelled the herbaceous cover over a considerable expanse. In fields adjoining the water, they ate maize and aubergines, but on the whole little damage was done by them to agriculture. Predatory birds, wolves, jackals and sheepdogs, were all said to hunt the coypu, the birds doing so particularly in the winter.

The coypu in Russia, as elsewhere, normally makes platform nests of herbaceous vegetation above ground-level, but it was found also to live in burrows in alder-hillocks enlarged from cavities from which the soil had been washed away by the water. This occurred particularly where there was no development of herbaceous vegetation, for instance on the steep mud banks of woodland watercourses. Burrows of this sort under trees are described from other countries, including its native haunts in S. America, but they are not usually very long. It appears that this rodent may sometimes take advantage of burrows made by other animals and enlarge them. On the whole, it appears that it does not burrow to a great extent unless there is an absence of cover or the protection afforded by deep water.

In 1943 a survey was made by the Bureau of Animal Population along part of the river Yare near Norwich, where a wild population of coypu was known to exist, and this survey was followed in 1944 by a more extensive one in Norfolk as a whole. At that time the coypus were known to extend along the rivers Yare, Tas and Wensum for about forty miles, and to live in the Rockland and Surlingham marshes. They were not then thought to have been reported outside a circle of about eight miles radius south, east and west of Norwich. Early in 1945, a further survey was made, especially on the river Yare, along which they were found to have extended their range. In the last ten years, they have certainly increased their range beyond this area, though a thorough survey has not yet been repeated. Not only are they much more widely spread in Norfolk, being recorded for example from Horsey, King's Lynn and Oulton Broad, and on the rivers Wissey, Waveney and Ant, but they are now known from East and West Suffolk and from Cambridgeshire. The most southerly of the East Anglian records so far is from Holbrook, near Ipswich, and the most westerly is near Wisbech. Apparently isolated colonies have also been reported from time to time in other parts of England, for example, near Lewes in Sussex, and near Slough in Buckinghamshire. Of course, although the animal has extended its range, there is no evidence that its numbers are increasing. Human predation has so far been an important factor, possibly the main factor, in keeping down the population. Good skins are valuable. In the summer of 1954 the price of 35 shillings per skin was quoted locally, and although this had fallen to about 25 shillings by last November, the return would still be tempting to would-be trappers in areas where coypus are sufficiently abundant. Naturally, as numbers fall, the labour of trapping is less rewarding. The flesh of coypus is edible, but it is doubtful whether it has ever been very much eaten in Britain, despite dark rumours concerning sausages and pies in the days of rationing. Predation by other animals does occur, and young coypus are probably taken by any carnivore large enough to tackle them. Stoats are thought to do this, also possibly herons, but there is little detailed knowledge of the predators of the coypu. I have seen a corpse of a juvenile coypu with the back of the head broken into, perhaps by either a stoat or a heron. Although the rodent is large, its very size and weight make it conspicuous and relatively clumsy, except when it is swimming. It is not a fierce animal in spite of its appearance and it is easy to trap; it seems likely that if it were ever thought necessary, it could easily be controlled and possibly even exterminated.

The effect of the animal on growing crops in Britain is not significant. Some damage to vegetables in waterside gardens and allotments does occur, but there is little damage to summer field crops. Instances have been known of persons deliberately growing small quantities of some plants, such as sugar-beet, in strips near to the water, in the hope of attracting and trapping the coypu. Barking of trees has not been recorded in this country, but captive specimens will do this. Burrows have been described, as in other countries, but no really serious damage to dykes and river-walls has been proved in Britain. Holes have been found, mostly in dykes rather than river-walls, but usually they are found not to have been initiated by this animal. Records made by the marshmen employed by the River Boards indicate that burrowing is not a common habit of coypus in this country and they are not therefore a danger to the

drainage system; the animal *can* burrow, but the exact circumstances in which it does so are not yet understood and may need to be studied. The reaily significant effect of the creature is on the natural succession of the aquatic vegetation, which forms its main food supply, its nesting material, and its hiding-place. It grazes the shoots of reeds (*Phragmites communis*), cuts up the rhizomes, and may completely clear the beds, converting them into open water. I have seen areas of some acres of open water in a tidal fen near Rockland Broad, which eight years ago were reed beds. The coypu also eats the reed-mace (*Typha*), pulling up the plants and eating the submerged parts and the roots, leaving the rest floating. It also does this with rushes (e.g. *Juncus* species), the appearance of the floating leaves, stems and bitten-off rhizomes being characteristic. The aquatic grass, *Glyceria*, is also eaten, but this plant seems either to stand up to coypu grazing better or to recover very quickly, as in some areas it has partly replaced the *Phragmites* reed-beds. Here and there in the midst of these open areas, old dead stools of the reeds can be seen projecting above the shallow water. Sedges such as *Cladium*, and water-parsnip (*Sium*), are also eaten, as are many other kinds of aquatic plants, but the really conspicuous phenomenon is the destruction of reed-beds where the coypu occurs in any numbers. If the animal increased sufficiently, the reed-cutting industry could be affected, but there is no prospect of this at present. It could be argued that the opening-up of the water is a good thing, within the present scope of the animal's activities. It could only change the face of the East Anglian scene if the coypu's increase were absolutely uncontrolled, which it is not at present. A possible effect in some places is on the breeding of certain birds, such as the water-rail, because the coypu does trample down the vegetation appreciably as well as graze it; this has been reported already by one observer in Norfolk, R. K. Murton.

There are well-authenticated accounts of this aquatic rodent staying completely submerged for half an hour. This is remarkable even in a diving animal, since half an hour is a long time of submersion for even a large seal, and is possibly twice as much as a beaver can endure. Investigation of the physiological basis of this should be a fruitful line of research, which I hope to undertake shortly.

Fur farming has thus led to the existence in the midst of our English country-side of a most interesting species of mammal. The true facts about it are really no less strange than the fairground myths with which this paper began.

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PHYSICAL SOCIETY EXHIBITION

It should be placed on record that the Physical Society this year held its exhibition (on April 25–28) not in the Imperial College of Science and Technology but in the New Horticultural Hall. This venue had the convenience of being central and it provided one enormous open space in which all the stands could be arranged on one floor in parallel rows (Kelvin Avenue, Faraday Avenue, and so on), all of which is less romantic, perhaps, but more practical than the hidden corners and endless corridors and stairs of Imperial College. The need for the first time to pay for its space no doubt made the Society shorten its usual six days—which used to go over the week-end and so give many thousands of people a chance of visiting the exhibition on their free Saturday—to four days.

The exhibits, being *new* by the ruling of the Society, and if we exclude the very many that were merely improvements on apparatus shown in former years, gave some idea of what is going on in the minds of research scientists and engineers and technicians concerned in practical developments under government control—there were fifteen stands for official research establishments—or commercially inspired. This year, if there were any general themes to be discovered among the wealth of exhibited apparatus they were concerned with the properties and manufacture and use of semi-conducting materials, the increasing automatisation in industry and research, and the continuing development of the atomic industry. Counting and timing devices are continually being improved and never a year passes without a visible progress report in this field. Cathode-ray tubes have settled down to being routine visual aids and are no longer the newest toy; there were less on show than in any year since the war.

Many firms were showing semiconductors and the transistors made from them. Now that the first ballyhoo about them is over and scientists have really got to grips with the fundamental atomics of the phenomena, reliable and consistent transistors are now being made, many of them synthetically. British Thomson-Houston, for example, showed the growing of one enormous silicon crystal as big as a small carrot. This crystal is cut in slices, and these then constitute one part of a transistor, the other being a different material such as indium. Germanium, on the other hand, is a "natural" semi-conductor, and it was the variation of its qualities that misled research workers a few years ago and held up progress in the new techniques. Now that the electronic basis of semiconduction phenomena is understood, the synthetic transistor that depends on junctions between dissimilar pure materials is an accomplished fact.

The standard of purity demanded is fantastic; even

visual spectroscopic analysis, sensitive to the presence of an impurity to about one part in a million, is not sensitive enough for purity assay in semiconductor research, and is moreover confusing and time-consuming to apply. In this connexion Metropolitan-Vickers has produced the first of its mass spectrometers for a more or less qualitative estimate of impurity level. (Two have already been ordered before the prototype was finished.) In this instrument two tiny electrodes are made of the material to be assayed. A very small spark is passed across the space between these electrodes in a hard vacuum. In this action positive ions of the various isotopes of the element are produced. These are accelerated by a high voltage, deflected electrostatically, then magnetically, both in such a way that the ions are separated out according to their mass numbers and give lines on a photographic plate. The result looks like any spectrum photograph, but the number of lines in it is small and equal to the number of isotopes of the element—copper has six. This small number of lines, well separated, makes the spectrum simple to interpret. The arrangement is that the photographic plate can be given a shift sideways and a second exposure made, longer than the first exposure by a known factor. Some half a dozen separate exposures can be made on the same plate, increasing in exposure time from the first to the last. The result is a series of spectra, exactly aligned, of increasing intensity. At some stage new lines appear and represent the impurity. In the photograph shown at the exhibition the impurity in the copper was silver and appeared in the third spectrum. The degree of impurity is measurable according to the time factor of the different exposures. As far as is known this apparatus is unique in the world. Steel-makers may well be interested in it for on-the-spot immediate estimation of carbon.

Transistors are tiny and absorb negligible power. They are reliable and need hardly any servicing. So there is a great interest in them commercially. Fortiphone made a special point of showing the "seven smallest electronic components in the world", designed to be used with and to take advantage of the tininess of a transistor, replacing even a miniaturised valve by something only a third the size. A high-tension generator for deaf-aid gear gave 30 volts at 100 microamperes from a 1·5-volt supply and yet occupied a space only $1\frac{3}{8} \times 1\frac{1}{16} \times \frac{1}{2}$ inches.

Two new developments in atomics reflect the concern with radiation hazards. Baker of Holborn showed an automatic blood counter. The chief pathological hazard of radiation is an anaemia caused by the penetration of radiation to the bone marrow where red cells are manufactured. A quick blood count of red cells is therefore necessary for the routine examination of people exposed to hazard. It has been developed in collaboration with Harwell. A specimen of blood is diluted to a known extent and put into the usual cell used for blood-cell estimation. This is on a stage which automatically moves backwards and forwards under the microscope, moving sideways at each passage, so that the whole of the glass cell is scanned. A photomultiplier above the slit where the image is formed gives a pulse for each blood cell that passes across the field. These pulses are then counted. Something like 20,000 red cells are counted automatically by this device in about four minutes.

Another radiation development was shown by Chance Brothers who have produced glass that does not change colour after irradiation. This stability is achieved by the addition of cerium oxide to the mix, and it can be used in the heavy lead glass used for radiation screens in isotope and other chemical factories processing radioactive materials.

Automatisation will mean an increased use of electronic computers. Many of these were on show. Ferranti showed one—called *Pegasus*—that has a "packaged" structure, that is to say, plug-in circuits that can easily be removed for servicing. It has been designed for calculations in industry and scientific research. Measuring only about $8 \times 7 \times 2$ feet, it is a remarkably compact instrument and can handle a multiplicity of "orders" given by punched tape. The National Physical Laboratory's new Electronics Division showed also its own magnetic storage drum for storage in a digital computer—a drum, incidentally, the material of which was made up at the N.P.L. from iron oxide and epoxy resins. Edison Swan showed a process controller suitable for the developing industrial automation. It can control six separate functions, such as turning on a gas burner, for example, so that they are performed in the right order and for the correct time.

A totally new machine for automatic inspection was shown by Kelvin Hughes. It was an automatic flaw detector based on ultrasonic radiation. The moving element that scans a specimen of metal of suitable size holds both transmitter and receiver. It scans by repeated traverses and any flaw is automatically recorded as a line on a moving paper, calibrated to indicate the exact position of the probe when the flaw triggers off a pulse. This machine, developed in the first place for use with boilers and extruded aluminium, is believed to be the only one of its kind in the world. No human attention is needed except at the beginning and end of a test.

The exhibition did not fail as usual to give a few individual researchers a chance to show and talk about their own work. Surely the prize in this category must go to Dr. D. M. Tombs of Imperial College. He showed a loudspeaker that used no power and depended on the corona "wind"—that which, produced by a Wimshurst machine, used to stream the hair on a doll's head in our schooldays. This discharge (at very high resistance) can be controlled by a ring of metal round, but insulated from, a point where the corona discharge takes place. This ring, in effect, is the "grid" of a triode (not thermionic) valve. A mosiac of point-discharge units, when a fluctuating voltage is given to the grid, produces variations in "wind" that, if of high enough frequency, are heard as sound. A response from zero frequency to 15,000 cycles per second was claimed for this ingenious device, hardly more than a scientific toy as yet, developed by Dr. Tombs as a sideline to his main consulting work concerned with the problems of disseminating airborne insecticides.

C. L. BOLTZ

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THE SEARCH FOR TECHNICAL INFORMATION

A. G. KAY

The advance of science and technology has brought about so vast an accumulation of facts that the task of finding specific details on specific subjects can look forbidding. But given a modicum of "know-how" the search for technical information becomes considerably easier. In this article a Patents and Intelligence Officer of a large industrial organisation has drawn on his long experience in this field and gives some hints that will help readers to solve many technical information problems for themselves. In the first half of the article, published this month, he deals with reference books, technical books and Government publications, of whose existence the searcher for technical data needs to be aware. The second part, to be published in our July issue, is concerned with the question of finding one's way about among scientific periodicals and patent literature, and it also describes the kind of services available from specialist libraries in general, and from the Patent Office and Science Library in particular.

The "do-it-yourself" attitude is gaining ground in this country. Economy is not the only reward to be found in carrying out yourself so many of the jobs which not so long ago were the preserve of the skilled tradesman; there is often a quiet satisfaction and pleasure in completing a job which you had previously left to someone else because you lacked the skill, the tools or the inclination to tackle it yourself. There are other tasks, somewhat more intellectual than that of repairing a broken window or replacing a faulty tap-washer, which might well be regarded in the same kind of way, and one of these is the searching for technical (and other) information. Normally, before we start on any of the more humble jobs we take care to watch the glazier or plumber at work so that we have some idea of how to set about it ourselves. This is not really possible when it comes to looking for information; we cannot trail round after the librarian or carefully watch what references he consults. For that reason I have provided a quick look at the librarian's tools and how they are used, so that when you next have this type of job to do you can seriously consider doing it yourself.

In this, and in a later article, I should like to discuss firstly some of the very many reference books available to virtually everyone who can read and has access to a good library—whether it be a public library, a reference library, a university or special library; and secondly I should like to indicate some of the various facilities and services which are open to bona-fide seekers after information. These articles are intended to interest those who have no qualifications for library work, but who nevertheless have occasion to look for information with little idea of how to set about it. They are not intended to be either exhaustive or comprehensive since that would be a completely impossible ideal. It is hoped, however, to cover enough ground to give some useful pointers as to what is available.

From time to time there arises the occasion to refer to straightforward facts, figures and information. This is usually the easiest form of hunt—if you know where to look! Let me assume that you are a complete innocent in these matters. First of all, then, there are available dozens of different reference books which cover almost the whole range of knowledge from broad general topics down to universal constants given to six places of decimals. No person can expect to be familiar with them all and few can hope to know intimately the range covered by more than a few.

The first and fairly obvious thing to do is to classify roughly in one's mind the type of information required—general, commercial or technical. Let us assume that it is technical. We have now to decide whether what we want can be considered as belonging to the fundamental sciences (such as the chemical, physical or medical), or whether instead it lies in one of the technologies, as for instance, textiles, plastics, metallurgy or chemical engineering. The rough classification finally decided upon will narrow down, initially at any rate, the field of search. Even in those reference books which cover more than one field it is often a great help to be able to restrict the search to one particular part of it.

Having reached this stage it becomes necessary now to consider a few actual reference books. I can give only a brief indication of the coverage of these, and I think it would not be out of place to say that it would handsomely repay many people to spend a few minutes just thumbing through some of these books whenever time can be spared. That is the surest way of learning what to expect from a particular work of reference. It is amazing what fascinating and out-of-the-way information one comes across in this way, and the nodding acquaintance with the various reference books so gained proves very helpful when one has to make a search for some specific data.

GENERAL TECHNICAL REFERENCE

I consider *Van Nostrand's Scientific Encyclopaedia* to be an excellent source of all sorts of technical facts and information, both general and specific. It covers an enormous range from aeronautics and astronomy down through botany, electronics, geology and photography along to zoology, encompassing in all twenty different and very broad subjects. "A feature of the Encyclopaedia is the progressive development of each topic beginning with a simple definition . . . and progressing to a final reflection of the more detailed scientific aspects" state the editors of this book in their preface, and they live up to that aim. One finds that as well as really clear definitions of terms the book frequently provides, where applicable, physical and chemical constants, explanations and discussions of processes and a variety of clear diagrams. I have not found it to suffer

significantly as some books do from its American origin, most of the terms and explanations being as acceptable in this country as they are in America.

A British counterpart in miniature (by comparison) is *Chambers's Technical Dictionary*. It is surprising in its broad sweep, and it is often quite adequate to answer the straight specific question. I would recommend it, in fact, as a very desirable acquisition for handy use on the desk.

Another vast work with a much more academic flavour is *International Critical Tables*. This is in seven volumes (plus an index volume) and provides numerical data of high authenticity and authority on a huge range of physical, chemical, astronomical and general technical subjects. Again, without going into detail, it is possible only to indicate that out-of-the-way material is to be found here such as the properties of hundreds of varieties of wood, numerical information on very many properties of glass, rubber, azeotropes, tables concerning surface tension, viscosity and spectra, as well as equilibrium diagrams for alloys. Every small section of the work is liberally supplied with references to the various authorities from which figures have been derived, and there is frequently a discussion of the means of formulating general equations of states and properties. This is an invaluable work for those carrying out fundamental investigations, and is equalled only by the various sets of tables published by the Smithsonian Institution of Washington which I have no space to discuss. There is one snag about the *International Critical Tables* (which does not apply to the Smithsonian Tables), and that is that they were published in 1927 and there has been no revision since that time. Much of the information they contain, of course, is not likely to have altered, but there are subjects which require a thorough overhaul now.

On a much smaller scale is Kaye and Laby's *Physical and Chemical Constants*, which covers much the same ground but on a minute scale as compared with the *International Critical Tables*. It has the advantage, though, of having an edition as late as 1948. It is also small enough and cheap enough to be a reasonable individual purchase.

PHYSICAL AND CHEMICAL REFERENCE

There are two books which might be said to be chemists' bibles—*Handbook of Chemistry and Physics* published by the Chemical Rubber Publishing Co. of America, and Lange's *Handbook of Chemistry*. The first is published annually, the second at reasonable intervals of three to five years. It is impossible in a few words to do justice to the scope of the tables and data presented in these two books. Of the two, I personally prefer the first work because in its 3000-odd pages it covers all that is generally thought of as physics and chemistry as well as mathematics, whereas Lange is confined more to chemical and physical chemical data—there is, as you might expect, quite a bit of overlapping between the two. In our own library, in about three out of every five occasions where a set of figures is required "off-the-cuff" it is in one of these reference books the answer is sought. The tables of squares and cubes and their roots, the conversion tables and physical constants of a long list of organic and inorganic compounds alone would be of value; to these are added hundreds of tables on such matters as x-ray crystallography, emission spectra, reflectance of light, compositions of foods, analytical reagents and so on which are not easily to be found elsewhere.

I cannot possibly deal with all the many books even on chemistry and physics and the next best thing, I think, is to direct your attention to the fact that there are others, merely by listing some of the more specialised ones. These represent but a small selection:

Seidell, *Solubilities of Organic Compounds.*
Solubilities of Inorganic Compounds.
Heilbron, *Dictionary of Organic Compounds*, which gives chemical and physical data for several thousand substances.
Thorpe, *Dictionary of Applied Chemistry*, an encyclopaedic survey of all aspects of technical and commercial chemistry.
Glazebrook, *Dictionary of Applied Physics.*

To this very short list I must add two works which are pets of my own. Both set out to do the same job, and the only difference between them is that one is very much fuller than the other. They provide formulae and recipes for thousands of compounds of interest alike to the commercial manufacturer, the occasional dabbler, the man at the bench and the individual who wants to make up a "bit of stuff" for himself. They tell you how to concoct hair-removers, paint-strippers, soaps, polishes, cosmetics, soldering fluxes, fertilisers, fireworks, wines, beers and what-have-you as well as instructing you how to remove stains, colour metals, make emulsions, prevent potatoes sprouting and giving a variety of other hints and tips to take care of everything to make one (nearly) self-sufficient. These treasures are *Henley's book of Formulas, Processes and Trade Secrets* and *Bennett's Chemical Formulae* (9 volumes to date!).

ENGINEERING REFERENCE BOOKS

Under this heading I have interpreted engineering very broadly to include mechanical, electrical, chemical and civil engineering as well as architecture.

The foremost British reference book on engineering in general is certainly Kempe's *Engineers' Yearbook*. It runs the whole gamut from straight mechanical engineering to such topics as lifting tackle, locomotives, lubricants, electronics, concrete and explosives. It contains seventy-nine such chapters and is up to date now since its complete revision in 1954.

A book I should like to mention because I think it would be useful in helping to provide a solution to a great many minor mechanical problems is one entitled *Ingenious Mechanisms*. In it are thousands of diagrams of mechanisms for performing all sorts of mechanical operations.

The next three books are all American:

Urquart, *Civil Engineering Handbook.*
Perry, *Chemical Engineers' Handbook.*
Knowlton, *Standard Handbook for Electrical Engineers.*

The first one is a cross between a textbook and a pure reference book in that it is not confined to simple statements of numerical data but has extended discussion on a great number of points. (The same remarks apply to the equivalent British work, Probst and Comrie's *Civil Engineering Reference Book*.) Perry is the answer to the prayers of all those engaged on work in the chemical processing industries. More than that, it is invaluable and comprehensive in the data presented on the various operations encountered—the technical application of chemistry and physics. Machinery, application of first principles, tables and graphs of conditions, costs and properties are all here and it would be difficult to see how it could be made more complete for the field of its purview. Perry's opposite number in the electrical field is Knowlton. The last edition of this was in 1949 and is as complete for electrical engineering as Perry is for chemical engineering.

The growing importance of instrumentation in all fields, not only of industry but of research, is reflected in the publication of the *Instruments Manual*. Again, this is not strictly a reference book in that principles, construction, setting-up faults and even the purchase of instruments for every possible type of work is dealt with and the pages are predominantly occupied with textual matter. The necessity to publish a completely new edition in 1953, only four years after the original, is an indication of the value placed upon it by those who require information on the subject.

Metals Handbook, published by the American Society for Metals, aims to provide "a single authoritative volume that will serve the needs of those who wish to know accurate facts, the specific meanings and the real significance of metallurgical subjects". I consider that it lives up to its aims—more than that it would be superfluous for me to say.

Although not an architect, I find much interest myself in thumbing through the *Architects, Builders' and Civil Engineers' Reference Book* and also through *Specification* (both British). Both contain descriptions, specifications, types of construction and costing of all sorts of building materials as well as facts and information on matters like insulations, paint defects and faults in timber. Despite their being directed to the professional man, they are of interest and value to the person who is concerned to look after his own property.

MISCELLANEOUS TECHNICAL REFERENCE

The lists of different reference books for different subjects could be extended many-fold, but however many I put in, however many subjects I included, there will always be someone who will feel that I should have put in this or that and I should have covered such-and-such a subject; it will no doubt be commented upon that I have confined myself to British and American titles, but I have done that because they are usually easier to get hold of and more readily intelligible to most people in this country.

As might be expected, it is the established sciences and technologies which are catered for best, but the range of reference books is continually being extended. Simply in order to show the type of subject for which handbooks and reference books may be found there follows a list of a few at random. From this you will realise that the answer to a specific inquiry may be found in one or other book of data; most of these are usually available in, or can be obtained by, a good reference library, especially if the query pertains to an established technology:

British Plastics Yearbook.
Modern Plastics Encyclopaedia.
Production Handbook.
Petroleum Data Book.
Mercury Dictionary of Textile Terms.
Handbook of Photography (by Henney and Dudley).
Handbook of Solvents.
Black's Veterinary Dictionary.
Heating and Ventilating Engineers' Data Book.
Naval Architects' Pocketbook.
Gardner's Chemical Synonyms and Trade Names.

GENERAL REFERENCE

Before leaving the subject of reference books I should like to mention briefly some general non-technical reference books. The amount of information obtainable by consulting some of them is probably not even dreamt of by the layman. Questions such as these may well become of importance during the course of an investigation: How many vessels and what tonnage passed through the Suez Canal during 1953? What was the distribution of population in Great Britain in 1951? How many man-hours were lost due to industrial disputes in 1954? I am not going to try to list all, or even many, of the general reference books in which answers to these and other miscellaneous questions may be found; I shall simply mention a few of the better known. Of these I personally find *Whitaker's Almanack* to be a magnificent standby, and I like to have an up-to-date copy of this annual publication within reach; it is the book I probably turn to most for everyday inquiries of all types. *Who's Who* is always useful, and so too is *Black's Medical Dictionary*, though after dipping into it you may find it difficult to convince yourself that you're as healthy as you feel. Here is a list of a few others:

Scope Yearbook.
The Annual Register.
World Almanack.
Debrett's Peerage.
Statesman's Yearbook.
World of Learning.
Webster's Biographical Dictionary.
A.A. Handbook.
Willing's Press Guide.

DIRECTORIES

Directories, yearbooks, university calendars and local reference books can be of real value even on near-technical points much oftener, I rather think, than the technical specialist may realise. Whether it is the board of directors of some company, the manufacturers of some article or another or the professor of some faculty, such factual information is usually to be found in one

of the type of publications just mentioned. In the *Directory of Directories, Annuals and References* there are 1300 titles, both in alphabetical list and in classified form so that that in itself is something to consult if you wanted to find out if there is any annual or reference book published on a particular matter. This still does not exhaust the possibilities—there remain the telephone directories, trade catalogues, atlases and gazetteers; it must not be forgotten that atlases such as Bartholomew's *Citizen's Atlas of the World* can yield quite a lot of information about air-routes, population, time-zones, rainfall and temperature.

This quick recital of the immense range of works of reference might, I feel, give rise to some pained bewilderment. The would-be seeker after information may perhaps consider that the transition from the state where he didn't know where to begin to the condition of being overwhelmed with titles has resulted in his being little better off and rather more dizzy. I have not intended, though, that this dissertation should be swallowed whole, but rather it has been my aim to awaken the realisation that there are mountains of facts and figures on a tremendously wide variety of subjects and to give some indication as to what and where. It is still necessary for the searcher to use his discretion and to make a wise choice of the material he searches.

Not all the information we may want is in the form of cut and dried facts or figures to be found in some reference book or other. What is required may not be found there at all or, as sometimes happens, a much wider discussion than can be given there is needed. I should like therefore to turn now from the chase after specific facts to the quest for less well-defined information and books.

BOOKS

Some people like to be kept informed about what books are available or are being published on particular topics. Most publishers are really quite eager to advise potential buyers about this sort of thing; as a rule they are only too glad to send a prospectus of forthcoming books and a catalogue of already published ones to anyone who takes the trouble of asking. They will restrict the information they send you to books about specific subjects, if you ask for that to be done, or will send you their general lists. Booksellers, especially the smaller ones, are not really equipped to do this. Incidentally, a list of all publishers in this country along with their addresses is to be found in *Whitaker's Almanack*. For a list of books published over a period *Whitaker's Cumulative Book Lists* are available somewhere in practically every public library. These lists can be obtained in volumes covering either one year or ten; there is a classified section so that you can quickly get a note of books published on a single subject over the past one or ten years—this will contain all the British titles, very many American ones and those of a number of other countries. *The British National Bibliography*, published weekly and bound annually, is probably also available for consultation in most reference libraries. This is probably of even more value than *Whitaker* for technical books to those who know the Dewey Classification system, as the book titles appear in that classified order. Another approach to the matter is to consult the catalogues of one or other of the bigger libraries; these are usually classified and it is simply a case of looking in the correct section—if there's any doubt about that . . . well, that's what the librarian is there for. It is amazing how many people fight shy of rummaging through library catalogues. These are not the private preserve of the library staff, they are there for all users of the library and there is no librarian breathing who would be at all reluctant to show someone in difficulties how to find what he wants. A useful list of carefully selected books has been compiled at the request of the British Council by E. R. McColvin. This costs 7*s*. 6*d*., is published by Aslib (4 Palace Gate, London, W.8) and is entitled *A Select List of Standard British Scientific and Technical Books.*

GOVERNMENT PUBLICATIONS

Government publications constitute one important source of technical information. An example (and one that is liable to be overlooked) is provided by the "Replies to Questions" in Parliament which give much factual information about scientific matters quite unobtainable elsewhere, and these are all faithfully recorded and indexed in *Hansard*, the record of the daily proceedings of both Houses of Parliament. Government publications in general, as well as the periodical lists of these, are available at H.M. Stationery Office bookshops in many of the large towns; where there is no actual H.M.S.O. bookshop there is usually an agent or bookseller who can get these publications to order. Again, public reference libraries usually have not only the period lists of H.M.S.O. publications but also many of the papers themselves. Full lists are published daily, monthly and annually; the monthly lists will probably be the most useful to DISCOVERY readers, along with the various classified "sectional" lists which give titles of all publications issued by specific Government departments (e.g. the D.S.I.R. and Medical Research Council), and which are revised periodically. Full particulars about the full range of lists available will be found in the H.M.S.O. Catalogue Service Leaflet, which is obtainable free on request. To those who have never inspected any of these catalogues it will certainly come as a surprise to find the enormous scope of Government literature on technical, scientific and agricultural matters amongst others. (In many British libraries you will also find similar lists from the U.S.A. issued by the U.S. Government Printing Office.) It is useful to know that H.M.S.O. will post any of their publications to any address, and it is simplest to send the cash and cost of postage with the order unless you have an account. It is possible to have a credit account with the Stationery Office but many people who make only occasional small purchases have, instead, a deposit account.

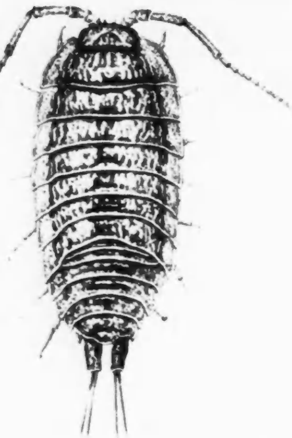


FIG. 1. The sea slater (*Ligia oceanica*).

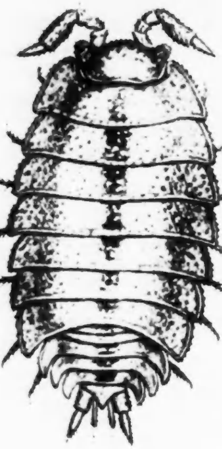


FIG. 2. *Platyarthrus hoffmannseggi.*

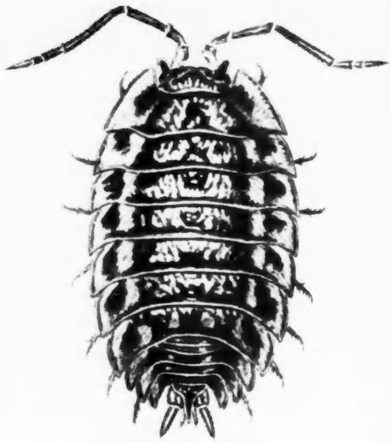


FIG. 3. The common garden slater (*Oniscus asellus*).

THE BIOLOGY OF WOODLICE

J. L. CLOUDSLEY-THOMPSON, M.A., Ph.D., F.R.E.S., F.L.S., F.Z.S.

In different parts of Britain there are many curious superstitions about woodlice. For example, in some places their presence indoors is regarded as unlucky, and any food on which they may happen to wander is considered poisoned. On the other hand, in certain districts until very recently, people would thrust a few live woodlice down the throat of a cow, believing this to have beneficial effects and "to promote the restoration of the cud". No doubt this is why in Shropshire and neighbouring counties slaters are sometimes referred to as "cud-worms". At one time too, woodlice were prescribed to be swallowed alive as a remedy for scrofulous symptoms and for diseases of the liver and digestive organs. It is surprising too how many local names have been given to woodlice: the late Dr. W. E. Collinge listed no less than sixty-five ranging from "Bibble-bugs" (Stafford), "Cheese-pigs" (Berkshire) and "Coffin-cutters" (Ireland) to "Monkey peas" (Kent), "Penny pigs" (Wales), "Sink-lice" (Lancashire and Stafford), and "Tiggy-hogs" (Northamptonshire). In America they are commonly known as "Sow-bugs".

Woodlice belong to the immense group of invertebrate animals known as the Arthropoda, whose bodies are segmented and provided with jointed appendages. Within this phylum, there are a number of classes which include the insects, arachnids, centipedes and millipedes—all these animals are predominantly terrestrial in habitat—and the more primitive aquatic crustacea. Crustacea are adapted especially for life in water, but there are a few which are interesting because they have become modified so that they can live on land. One example is afforded by the land-crabs, another by the woodlice. The latter belong to an order that contains many fresh-water and marine species and is known as the Isopoda. The sub-order Oniscoidea of the Isopoda comprises the slaters, a homogeneous group containing several species adapted in varying degrees to life on land. The geological history of the Crustacea is a long one and remains occur in the Old Red Sandstone of the Devonian period and in the Carboniferous Coal Measures. Fossil woodlice, however, have not been found below the Upper Eocene, which might suggest that colonisation of the land has been achieved somewhat late in the history of the group. When they do appear, however, fossil woodlice are generically indistinct from living forms and Prof. A. Vandel believes that the ancestors of woodlice became terrestrial during the second half of the Palaeozoic era. He bases this conclusion on the fact that all the main types of organisation within the Oniscoidea have a world-wide distribution and consequently must have a very ancient origin.

The most primitive and at the same time the least well adapted of the woodlice to terrestrial conditions are littoral species belonging to the family Ligiidae. There are two British species in this family, *Ligia oceanica* (Fig. 1), the largest of the British woodlice (this animal is up to 30 mm. in length and rather more than twice as long as broad), and the smaller *Ligidium hypnorum* which is sometimes found far inland, but always in the neighbourhood of water. The family Trichoniscidae also occur in very moist places but the Porcelliidae and Armadilliidae are found in progressively drier localities. Now this sequence is also one of increasing morphological specialisation within the group, the significance of which will be considered below.

RESPIRATION AND THE SKIN GLANDS

The clearest adaptation to terrestrial life is to be found on the five anterior abdominal appendages which are known as "pleopods". These function as gills in aquatic Isopods and they retain a respiratory function in terrestrial forms. They can be seen to beat rhythmically like gills in individuals of even fully terrestrial species like *Porcellio scaber* and *Oniscus asellus* when these are placed in water. Perhaps this represents some vestigial behaviour pattern, although it is more likely to be a reflex response to remove water from the respiratory surface. The pleopods are variously modified and in the more advanced forms bear tufts of invaginated tubules forming "lung-trees" or "pseudotracheae". Each tree opens to the exterior by a slit-like aperture near the edge of the pleopod, and the minute ramifying tracheae are thin-walled tubes surrounded by blood which carries oxygen to the tissues of the body.

The pleopods are probably kept moist when the air is dry by water that diffuses from the body fluids of the animal. At one time it was believed that certain skin glands known as "Weber's glands" played an important part in respiration. For nearly half a century the concept that these glands secreted a fluid which moistened the gills crept into almost every textbook, and great therefore was the surprise of Dr. H. Gorvett, who has made a special study of the glands of woodlice, to find that "Weber's glands" do not in fact exist in the animals; nor did he find them mentioned in the publications of their supposed discoverer!

At least five kinds of skin glands occur in woodlice, of which the rosette and lobed glands have so far been investigated by Gorvett. Some of the latter discharge an acid secretion that smells of butyric acid; others contain a liquid that is odourless and neutral. The function of these glands is probably to act as a deterrent to enemies, principally hunting-spiders. They are thus analogous in function to certain glands present in millipedes, harvest spiders and many insects.

THE SEA-SLATER

The sea-slater, *Ligia oceanica*, has a wide distribution around the shores of Britain and indeed of practically the whole north coast of Europe; it also occurs in France, Spain, Morocco and America. Although never found far from the sea, it is truly terrestrial and can withstand prolonged submersion in sea-water only if this is well aerated. Immersion in fresh water is more rapidly fatal. It is normally found in deep, narrow crevices in the rocks just above high tide level, under stones on sandy beaches or on the sides of quays: hence the name "quay-louse" or "quay-lowder". In St. Kilda *Ligia* has been found in the crevices of boulders over 450 feet above sea-level, but on that exposed islet sea-spray is often blown to that height.

The colour of *Ligia* ranges from a dark greyish-green to a light dirty brown, while young specimens have two light-coloured patches on the middle of the dorsal side. The British sea-slater, *Ligia oceanica*, like two related American species, shows well marked colour responses due to the expansion and contraction of colour pigment cells or "chromatophores", so that they become light when placed on a white background and turn dark on a black background. In addition there is a diurnal rhythm of colour change whereby they tend to be dark by day and pale at night.

Like most other woodlice, *Ligia* is nocturnal in habit and emerges during the night at low tide to feed on seaweeds and on any decaying animal or vegetable substance it may find. In captivity cannibalism frequently takes place. The creature is strongly photo-negative and tends to remain under cover on moonlight nights.

The family Trichoniscidae includes a number of small, elongated woodlice that are fairly widely distributed in damp places under moss, bark, fallen leaves, logs and so on. The Oniscidae are less dependent on moisture, but the common *Philoscia muscorum* which can be distinguished from the garden *Oniscus asellus* by its narrow body and pretty marbled appearance is again usually found in moist situations under rubbish heaps, damp moss and the carpet of dead leaves in woods.

ANT GUESTS

A curious little white, blind woodlouse easily recognised by its broad, flattened body up to 3·6 mm. in length with denticulate edges to its segments and short, stout antennae is *Platyarthrus hoffmannseggi* (Fig. 2). This species occurs throughout the British Isles and the rest of Europe, and its range extends into North Africa. It is usually found in the nests of ants and the burrows of wood-boring beetles.

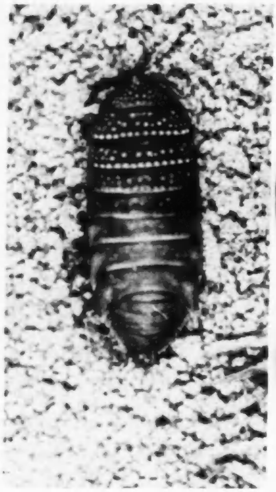
A New Zealand woodlouse, *Trichoniscus commensalis*, has independently evolved the same habit of associating with ants.

One of the largest and commonest of woodlice is the garden-slater *Oniscus asellus* (Fig. 3) which reaches a length of 15 mm. and about half that width. Again the pleopods are without pseudotracheae, but *Oniscus* seems to wander in drier places than any of the species mentioned previously.

A number of species occur in the family Porcellionidae of which *Porcellio scaber* is the most usual and has been recorded from all over the British Isles. This creature is even larger than *Oniscus asellus* and very variable in colour, but it is usually a dark slaty grey with irregular lighter markings. This species can be recognised by the transverse rows of small tubercles that cover the back of the head and body. All the members of this family are adapted to live in drier conditions than those that suit the other species of woodlice I have mentioned.

DESERT WOODLICE

To the same family as *Porcellio* belongs the remarkable desert woodlouse, *Hemilepistus reaumuri* (Fig. 4), which is not uncommon in North Africa and the Middle East. During a short expedition to Southern Tunisia in April 1954, I found this species in a number of different localities where the sand was fine and firmly packed in the alluvial plain north of Kairouan and in several places along the bed of the Oued el Melah. The animals live



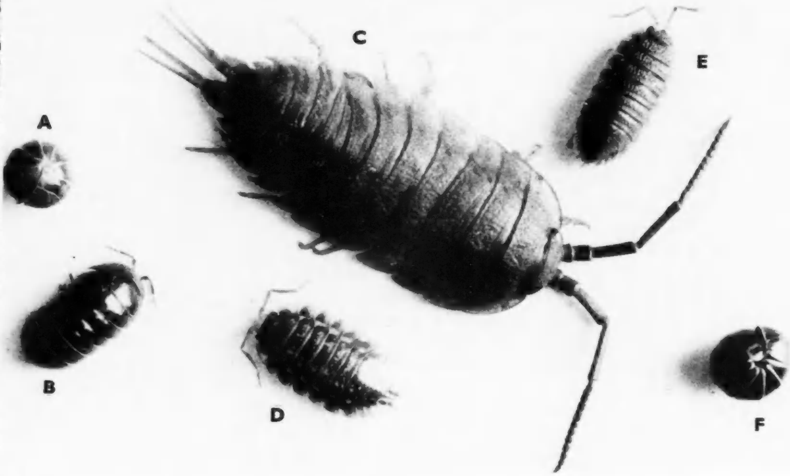


FIG. 4. A desert woodlouse, *Hemilepistus reaumuri*. FIG. 5 (*right*). Group of woodlice, twice natural size. (*Courtesy, Dr. E. B. Edney and* New Biology.)

A—B *Armadillidium vulgare*. D *Oniscus asellus*.
C *Ligia oceanica*. E *Porcellio scaber*.
F is not a woodlouse, but a millipede, *Glomeris scaber*.

together in vertical holes 5–6 mm. in diameter, and many centimetres in depth. I excavated one hole to a depth of over 25 cm. without finding any sign of reaching the bottom. A digging reaction is released by a temperature of 35°C if the soil is dry, and 45°C if it is moist. The head is placed against a small stone or some other rigid body: the anterior legs then lift the sand backwards while the posterior ones throw it away. Sometimes several animals combine to dig a single hole and frequently two woodlice can be seen head to head while they are digging.

PILL BUGS

Finally we come to the family of pill-woodlice or Armadilliidae, so called because they have the habit of rolling into a ball like a little armadillo. The ability to do this is by no means restricted to this family, however, but has evolved independently in several diverse groups. In forms that can curl up completely the head has become flattened in an antero-posterior direction so that its height is much greater than its length and the front part is covered by the last abdominal appendages or uropods when the animal rolls up. (In other woodlice the uropods project like a couple of small tails from the hinder end of the body.) The most common British species is *Armadillidium vulgare*, sometimes called the "Pill bug", which reaches a length of 18 mm. and is a little more than twice as long as broad. The colour varies from completely black to pale yellow, but the most usual shade is light grey. This species is widely distributed throughout the country but is particularly abundant on calcareous soils and is extremely common on the North and South Downs. In my own garden where the soil is acid it is uncommon and seems to be restricted to a small area near the remains of an old lime heap.

REPRODUCTION

Like other Crustacea, woodlice carry their eggs in a thoracic "brood pouch" and a whole family of newly hatched young may be found huddled up on the underside of the mother. The number of eggs varies from seven per brood in *Trichoniscus* to 100–200 in *Armadillidium*.

The newly hatched larvae have a distinct head and eyes, segmented body and short, stumpy limbs. They are incapable of movement for the first three days as their appendages are tightly doubled against the body. At this stage they are kept very moist, but as their size increases the fluid in the brood pouch gets less. The young emerge over a period of two or three days, and the first moult occurs within twenty-four hours of their emergence. The period between the first and second moult is the most critical in their lives because if the soil is dry at this time they die, while if it is too moist they are usually killed by fungi. Later they are more resistant to both drought and fungal attack. They are quite long-lived, and seldom breed until they are two years old.

Woodlice are omnivorous and no doubt useful as scavengers. Unfortunately they do not confine their attention to dead and decaying matter but sometimes attack seedlings, ripe fruit such as plums, peaches or melons, and mushrooms—indeed they will eat anything that is soft and juicy, though they do more mischief by disfiguring than by consuming any large quantities. They

are sometimes difficult to dislodge from hot-houses as they find shelter in every little crevice. (Some of the modern insecticides, e.g. DDT and Gammexane, cope effectively with this problem.)

WATER RELATIONS

Woodlice have little ability to prevent loss of water by evaporation and excretion, and although they can regain lost water both by actively drinking and absorbing moisture through their pleopods, they can only survive on land as a result of behaviour mechanisms that keep them in cool, moist places.

During the day they normally collect at the moist end of a humidity gradient and avoid the light; it is at night that dispersal to new environments mostly takes place. The writer has recently demonstrated in *Oniscus asellus* changes in the physiological response between day and night that can perhaps be correlated with the ecology of the species as follows: a fall in the intensity of the humidity response after dark enables the animals for a time to walk in drier places than their daytime retreats, but increased photo-negative behaviour after exposure to dark ensures that they return to cover at daybreak, and thus no doubt avoid the early bird! On the other hand they become photo-positive in dry air, so that if their daytime retreat should dry up, they are enabled to wander in the open until they find another more suitable, damp retreat.

In a recent review of the adaptations of woodlice to the terrestrial habitat, Dr. E. B. Edney concludes that different species can withstand terrestrial conditions of drought to varying degrees, but probably all species spend most of the time in an atmosphere saturated with water vapour and merely differ in the length of time that they are capable of surviving away from dampness.

Thus even *Armadillidium* can only venture into dry places with impunity for comparatively short periods. Edney also suggests that the reason why so little progress has been made toward full exploitation of the land by woodlice may lie in the fact that the conquest of the land by the Isopoda took place via the littoral zone, for *Ligia* and *Halophiloscia* are undoubtedly primitive morphologically. Now animals crossing this zone may well be subjected to extremely high temperatures, and the ability to lose heat by evaporation of water may have considerable survival value in all species.

Concluding, as we began, with superstitions, it does not seem unlikely that there may be some truth in the idea that when woodlice are seen abroad during the daytime it is a sign of rain!

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ALUMINIUM AND ITS ORES

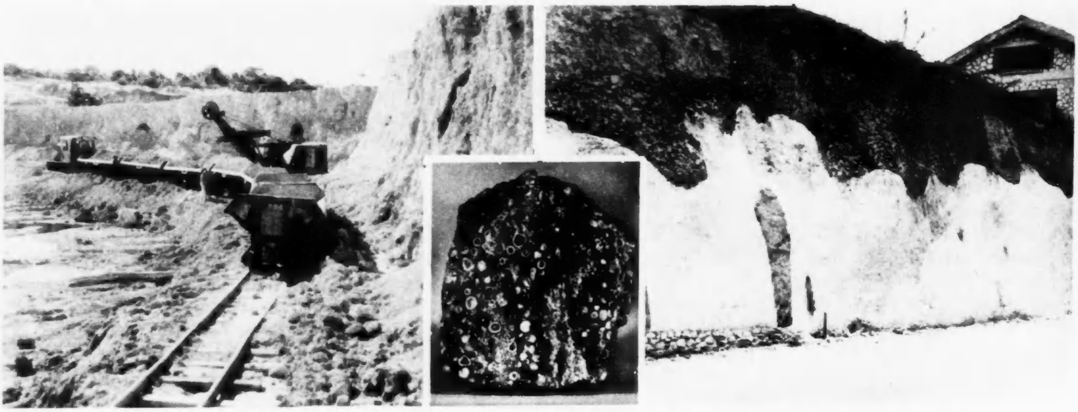
V. A. EYLES, B.Sc., F.R.S.E., F.G.S.

The aluminium industry is a young one, compared with those producing tin, copper and iron, which have been in existence for two thousand years or more. It is little more than a hundred years since the metal was first isolated from its compounds, and just a hundred years since commercial production (on a very small scale) was first commenced. Today, the total output of aluminium is so large that it has overtaken its rival, copper, in the race for second place after iron, as the world's most important metal.

The industry has had to contend with many technical and scientific difficulties; and much has been written about the part played by chemists, physicists, metallurgists and engineers in overcoming these difficulties. In these accounts the nature and origin of the raw materials from which the metal is extracted tends to be taken for granted. Probably, too, few users of the finished metal know whence it comes.

In a year in which attention is being focused on the centenary of the aluminium industry by the exhibition which the Aluminium Development Association is organising at the Festival Hall, London, this month, there will be an interest in the nature and origin of the raw materials used in the production of the metal.

The story of the development of the aluminium industry is an interesting one. It starts in 1854, when the great French chemist, Henri Sainte-Claire Deville, announced to the Academy of Sciences in Paris that he had found a new way of preparing metallic aluminium. Hitherto its preparation had proved so difficult, even on a laboratory scale, that its properties were not fully known. Deville had now isolated sufficient metal to enable him to determine these, and to describe them. He was so enthusiastic about the new metal that, even at that date, he prophesied it would have a great industrial future. However, although Deville's announcement aroused great interest, outside France as well as in it, and many attempts were made to find a commercially successful method of preparing the metal, the sodium reduction method then generally in use proved too costly for much industrial progress to be made. It was not until 1886, when a new process was, by a remarkable coincidence, discovered and patented independently—and almost simultaneously—in the United States and



Left: Mining bauxite in British Guiana. *Right:* A Jamaican bauxite deposit of the red "terra rossa" type overlying limestone. *Inset:* Gold Coast bauxite showing characteristic oolitic structure (quarter natural size).

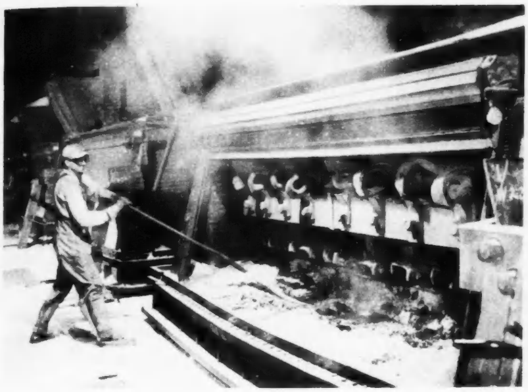
in France, that the industry really began to expand, and since then the expansion has been continuous. The new process, the Hall-Héroult process, has proved ever since, and in spite of much subsequent research, the only really satisfactory method for the large-scale production of aluminium. It produces aluminium by the electrolytic dissociation of alumina (Al_2O_3) dissolved in molten cryolite, a double fluoride of sodium and aluminium with the formula $AlF_3 . 3NaF$. The industry therefore requires two basic raw materials, pure alumina and cryolite. The latter mineral had been shown, by both Hall and Héroult, to possess just those unique physical and chemical properties necessary for their purpose, including the power, when fused, of dissolving alumina, and acting as an electrolyte, from which metallic aluminium could be deposited on passing an electric current through the solution.

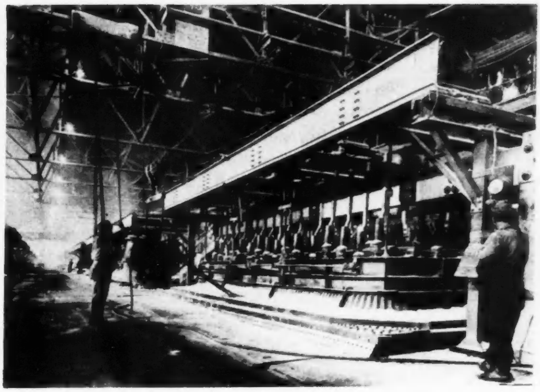
Cryolite is a rare mineral, so rare that there is only one deposit known that is of sufficient size to warrant economic exploitation (see DISCOVERY, Dec. 1949, p. 387), and the story of the discovery of that deposit is a fascinating one. In the 18th century, missionaries visiting Greenland sent home to Denmark, as an ethnographical curiosity, some specimens of a soft white substance that the fishermen used as weights on their fishing gear. This material was found by a Danish chemist, Prof. Abildgaard, to contain fluorine and aluminium, and he gave the new mineral the appropriate name of cryolite on account of its ice-like appearance.

A little later the precise locality from which the cryolite came was found, largely by accident, by a German mineralogist, whose parents had named him Johann Georg Metzler, but who later changed his name to Giesecké. He lived from 1761 until 1833. After studying mineralogy under Werner at Freiberg, Giesecké moved to Copenhagen, where he taught mineralogy and sold minerals, and then in 1806 he was sent by Christian VII of Denmark on a scientific expedition to Greenland which lasted seven years. It was in September 1806 that he came across the famous cryolite vein of Ivigtut, on the Arsuk fjord.

At Ivigtut cryolite occurs as the main constituent in a huge vein of granitic material. After Giesecké's discovery it was exploited commercially, for the preparation of sodium aluminate, which has some industrial applications. Once, however, the Hall-Héroult process was put into operation on a commercial scale, the demand for cryolite increased steadily. Fortunately, the Greenland deposits have proved sufficiently extensive to meet these demands, at least until comparatively recently, though now a proportion of the cryolite used commercially is synthetised from fluorspar. Nowadays, of course, as far as the aluminium industry is concerned, cryolite is used simply and solely as an electrolyte, and is not expended, at least theoretically; in practice a substantial amount of cryolite is used up in the running of the electrolytic cells, and the demand for new supplies of the mineral comes from the need to make good production losses as well as from the need to charge new cells brought into operation as the aluminium-producing industry expands.

In passing, it is worth recalling that in the days before the invention of the Hall-Héroult process, various materials were used in the preparation of aluminium, and the first metallic aluminium ever prepared in Britain was made by the reduction of cryolite itself by means of metallic sodium. This experiment was carried out by Allan Dick, under the supervision of the famous metallurgist Dr. John Percy, in the laboratory of the old School of Mines in Jermyn Street, then under the control of the Geological Survey. The strips of metal made were exhibited to the members of the Royal Institution by Faraday, on March 30, 1855. These specimens, now in the keeping of the Science Museum, at South Kensington, were again shown to the members of the Institution a century later on the occasion of the Friday evening discourse on March 25 of this year, when Mr. George Boex, a director of the British Aluminium Company, lectured on "A Century of Aluminium".





Electrolytic Production of Aluminium Metal

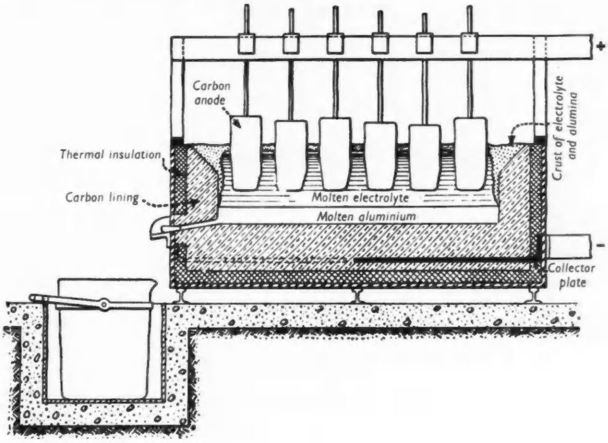
(*Top left*). In aluminium production a solid crust forms periodically at the surface of the molten electrolytic bath, and this has to be broken—an operation known as "punching the pot".

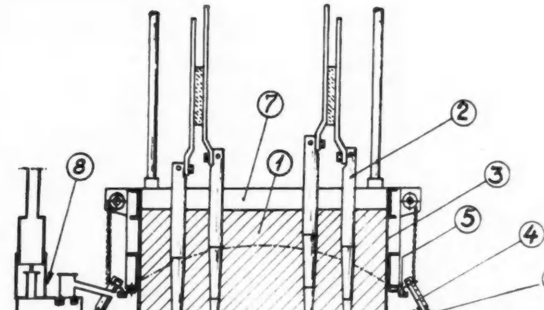
(*Top right*). An aluminium reduction furnace with Soderberg anode at the Lochaber works of the British Aluminium Co. Ltd.

(*Centre*). This diagram of an early type of reduction cell (in effect this is both a furnace and electrolytic cell) shows the essence of the Hall-Héroult process. The cell is first charged with cryolite. When the anodes are lowered on to this, electric current flows and the cryolite melts. Highly purified alumina is added, dissolves in the cryolite and is then decomposed electrolytically. The aluminium that is liberated sinks to the bottom; oxygen is also set free, to burn away the red-hot anodes. Nowadays about two-thirds of a ton of carbon is used up for every ton of metal produced.

(*Bottom*). The process has been developed to attain continuous operation, using this kind of cell known as the Soderberg Electrode Furnace (of which various types have been evolved). In this diagram the anode takes the form of a block; as the carbon is eaten away at the bottom the anode is built up at the top by the addition of a carbon paste. Alumina is added to the bath continuously.

1. Electrode	5. Alumina Seal
2. Conductors	6. Cryolite Crust
3. Electrode Casing	7. Electrode Cover
4. Furnace Cover	8. Gas Burner





Although expansion in the use of cryolite is limited, the supply of alumina has to be stepped up continuously as the demand for metallic aluminium increases, and it does not appear that saturation-point has yet been reached. The alumina of commerce is prepared almost entirely from one source, from the rock known as *bauxite*. As with cryolite, the discovery of this ore was largely a matter of chance, but unlike cryolite it has now been found to occur extensively in many parts of the world.

Bauxite was first discovered not long after cryolite, not, as is generally stated, in France, but in West Africa. The circumstances surrounding the discovery are interesting. In 1820, or 1821, a certain Frenchman, M. Blavier, apparently a mining engineer on the staff of the Corps Royal des Mines, sent to the École des Mines for examination some samples of a reddish rock, believed to be iron ore, which came from Les Baux, a picturesque Provençal village between Marseilles and Avignon. They were analysed by Pierre Berthier, an experienced mineralogical chemist, who reported that the rock, apart from 27·6% iron oxide, consisted almost entirely of hydrated oxide of aluminium, which he found to be present as a separate mineral and not combined with the iron. The figures he gave, though doubtless inaccurate by modern standards, are undoubtedly those of a high-grade bauxite. In this report, Berthier stated that, although as far as he knew, this was the first record of alumina occurring in this form in Europe, he had already found it in a rock from French West Africa with a similar composition, which he had analysed and reported on a year previously. This rock had been collected by a French traveller, G. T. Mollien, from a locality, Fouta Diallon, in Haut-Sénégal (French Guinea) where the natives obtained iron ore for smelting. While some specimens from this locality proved to be good iron ore, one of them—that referred to by Berthier—though richer in iron and poorer in alumina, than the material from Les Baux, had a composition quite typical of a low-grade ferruginous bauxite (see Table I). Thus, while it is commonly stated that bauxite was first discovered at Les Baux, it seems clear that the first bauxite to be described was that collected by Sénégal. It is known now that bauxites of the type known as *aluminous laterites* (see below) are quite common in this part of Africa.

However, it was the deposit at Les Baux that was first worked as a source of alumina, and that gave its name to the rock now known as bauxite.

THE NATURE OF BAUXITE

There is one interesting point about bauxite. No matter what its geological origin, it does not vary much in chemical composition. It is a rock characterised by the presence of large amounts of free alumina, in the form of one or more hydrated oxides—in particular, gibbsite ($Al_2O_3 . 3H_2O$) and boehmite ($Al_2O_3 . H_2O$)—together with certain impurities, generally iron, titanium, and silica. The amount of alumina present, which is, of course, the most important commercial consideration, varies inversely with the amount of these impurities. Some bauxites contain up to 20% or even 30% iron oxide. Titanium, though almost universally present, does not usually exceed about 5%. The amount of silica present is variable, but in a high-grade bauxite should be less than 3% to 4%.

Geologically speaking, almost every gradation from an iron-free high-alumina bauxite to an iron ore with little alumina can occur in nature. When required for the manufacture of aluminium, however, the alumina present should reach 50% at least. Bauxite has a number of other commercial uses.

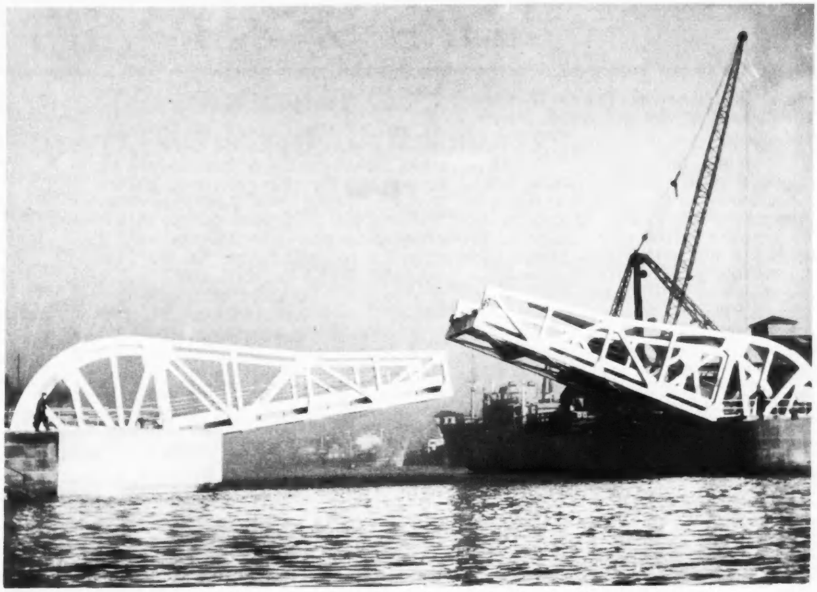
THE ORIGIN OF BAUXITE

It is well known that alumina is a widespread and very plentiful constituent of the earth's crust. In any particular rock it usually occurs in combination with silica, in one or more of the numerous naturally occurring complex silicate minerals, such as feldspar, kaolinite, mica, hornblende, garnet, and so on. Why, then, is it also found in nature as an oxide, uncombined with silica? We can answer that question in respect of many bauxite deposits, but not all. There are, geologically speaking, two types of bauxite. The origin of one type, the variety known as "aluminous laterite", is quite well understood. It is formed as a result of the operation of the geological process known as weathering. (This general term covers the various natural processes by which rocks at the surface of the earth are decomposed and disintegrated, one of which is chemical weathering.) Laterite, including aluminous laterite, is produced by the chemical alteration of rocks containing aluminium and iron (e.g. basalt, shale), under certain physiographic and climatic conditions. The conditions are those that generally prevail in tropical or sub-tropical countries, on high, badly-drained plateaux that are subject to seasonal rainfall. Such conditions are commonly found in, for example, peninsular India and central Africa, where bauxites are being formed today. Similar conditions prevailed from time to time in past geological ages, so that we have ancient as well as recent deposits of bauxite. For example, the low-grade deposits in the north of Ireland, which were worked as an emergency source during the last war, were formed at least

TABLE I. *Percentage Composition of Four Bauxite Specimens*

	A	B	C	D
Al_2O_3	58·8	52·1	52·0	40·0
SiO_2	1·4	0·7	—	2·0
Fe_2O_3	7·2	20·5	27·6	33·6
TiO_2	1·9	2·5	—	—
Combined water	30·6	24·2	20·4	24·7
	99·9%	100·0%	100·0%	100·3%

A = High-grade bauxite (aluminous laterite) from the Gold Coast.
B = Bauxite ("terra rossa" type), from Jamaica.
C = Berthier's original analysis (1821) of bauxite from Les Baux, France.
D = Berthier's original analysis (1820) of low-grade ferruginous bauxite (aluminous laterite) from Fouta Diallon.



Aluminium alloys have had a revolutionary impact on engineering. This picture shows the world's first aluminium-alloy bascule bridge which was opened at the Port of Sunderland in 1948.

10 million years ago, and possibly much earlier, in the middle of the Tertiary era. In fact, laterites are known to have been formed at least as far back as the Carboniferous period, over 200 million years ago.

Briefly, lateritic weathering is brought about by water percolating through the rocks at, and immediately below, the surface. As a result the complex alumino-silicate minerals decompose, and the silica, thus freed, together with certain other oxides (those of calcium, magnesium, sodium and potassium) are removed in solution, leaving behind a rock containing hydrated oxides of aluminium and oxides of iron and titanium. This process may, in course of time, affect the underlying rock to a depth of many feet—though it probably takes some hundreds of thousands, if not millions, of years to do so. We are then left with a superficial crust of "laterite", which may be highly ferruginous, or highly aluminous. Other physical and chemical changes take place at the same time. The iron and alumina tend to segregate into discrete layers of ferruginous laterite (iron-ore) and aluminous laterite (bauxite). The alumina tends to form little spherical concretions known as "ooliths" or "pisoliths"; hence the oolitic structure, so common in bauxites, which is seen on p. 252.

As mentioned above, there is another type of bauxite, whose origin is still a matter for argument. Chemically, it does not differ in any marked degree from the lateritic bauxites, but geologically it differs in being found in close association with limestones. It is widespread in occurrence throughout southern Europe, in association with sediments of various geological ages, from the Trias to the Tertiary, and is known as the "terra rossa" type of bauxite, because it generally resembles the red earths that form today on the weathered surface of limestones in some countries. The "terra rossa" bauxites generally fill depressions and cavities (formed by solution) in old limestone land surfaces, and such deposits are therefore very irregular in shape, size and distribution. The first bauxite deposit of this type to be discovered was that at Les Baux, but since then many others have been found—and are exploited in various parts of southern Europe, in Spain, Italy, Jugoslavia, Hungary and elsewhere. A notable example from outside Europe is provided by the deposits in Jamaica, which have been quite recently opened up commercially on a large scale.

How are such bauxites formed? There is difficulty in assuming that they originated in a manner similar to the aluminous laterites, through the weathering of an aluminous parent rock, because they rest on limestone and there is no visible evidence indicating that they might have been formed from some other rock. Now, limestone contains no alumina, except as a minor impurity, and it would therefore require the weathering of enormous thicknesses of limestone to form bauxite deposits of the thickness now found in southern Europe. While some geologists may believe that, in spite of this difficulty, the "terra rossa" bauxites were so formed, others, including the writer, incline to the belief that originally they were formed from some rock other than limestone in a manner similar to the aluminous laterites, whatever may have been their subsequent geological history. Both explanations encounter difficulties, and the origin of the "terra rossa" bauxites remains a geological puzzle. Whatever the answer, it is fortunate that deposits were found in France at so early a date, for otherwise the development of the aluminium industry might have been greatly retarded.

(The four column-width photographs are reproduced by courtesy of the following firms: Demerara Bauxite Company, Alumina Jamaica Ltd., Reynolds Metal Company, British Aluminium Co. Ltd.)

THE BOOKSHELF

Power Today and Tomorrow

By F. Sherwood Taylor (*London, Frederick Muller Ltd., 1954, 192 pp., 15s.*)

This is the latest of Dr. Sherwood Taylor's many notable books which have been written to explain scientific matters to Everyman. Indeed in his preface the author states that it is intended to supply the educated man with knowledge of the general principles of the means by which man wins and uses energy. This book deals in detail with the source, transformation and use of every form of power—coal, oil, water, wind, tide, electricity and nuclear energy.

There are three primary sources of energy available to man: (1) the sun and the interior of the earth; (2) the mechanical or energy of the relative motion of sun, earth and moon; and (3) the conversion of matter into energy, made possible by nuclear physics. But so far man has been able to utilise only two of these sources, namely photosynthesis (the source of all our fuels—coal, oil, peat, wood) and water power. At the present time the former produces 98·5% of the power we use, while hydro-electricity makes up only 1·5%. There are, of course, the untapped sources of wind, tide, solar radiations—a store of theoretically liberable energy and now, in this atomic age, the possible use of the 200 lighter and very plentiful elements would release power untold.

Each chapter deals with the known sources of power, and the descriptions are written simply and in the extremely lucid style we have come to expect from the author. There are excellent diagrams and photographs to illustrate each subject, and there is a complete absence of technical jargon which can so easily spoil the reader's enjoyment. And the book is not without humour. For example, "Firing a boiler is evidently an art, if done by hand, and a science if done mechanically." He goes on to show that steam-raising plants vary in efficiency from 55% to 90%. For anyone who has not had the opportunity to visit gas ovens, brickworks, coal mines, then Dr. Taylor's book will be your guide. But he also brings the question of coal utilisation nearer home and reminds us of the wastage from open fires, and informs that 35 million tons of coal are burned every year in domestic grates. Then quite dramatically he admits that he has burned nothing but *wood* for many years in his own house, not for any scientific reason but because he prefers its pleasant smell, its attractive appearance, and because stoking of such a fire becomes an art as well as a hobby! In other words, it is not enough to assess domestic heating solely in terms of thermal efficiency. For example, one has to take into account the damage done by coal smoke in this country, which the author describes in clear and concise terms. As to the question: *How much heat do we get for our money?* he gives the answer in a set of excellent tables which show the proportion of heat utilised by means of different appliances together with the relative costs. Science provides the facts and the figures, but the author states in his own inimitable manner, "I fear that you will choose not the most economical one, nor that which makes the best use of the fuel supply, but rather that which combines the most comfort with the least labour!" But I also must quote his criticism of the design of the heating system in many old houses in this country, of which the author is a sufferer. "From the stove the primary circulation sets off on its Odyssey through many yards of unlagged pipes to the hot water tank. . . . If I want a quart of hot water in the cloakroom I have to run off the cold water in the pipe, and the hot water that takes its place has to heat up perhaps ½ cwt. of iron, so that I have to run off 5 to 6 quarts of water, cold and warm, before the tap runs hot." There are many of us who are fellow-sufferers.

On the practical side this book contains excellent hints on the choice of open and closed fire grates, cooking stoves, gas cookers, electric cookers and hot-water systems with a detailed account of their advantages and disadvantages.

In the chapter dealing with Man and Power, Dr. Taylor shows how countries which have the raw material and supplies of power are the sources of the world's wealth. And in those countries there are better housing conditions, power for farms and factories to produce more food per acre and more goods per man-power. But in the future there will be a constant demand for increased energy if industrialisation takes place on the same scale as it has done in the last fifty years in the United States, and if the standard of living increases in all parts of the world. The result will be that coal and oil must be supplemented by other sources. It would seem from estimates that there is still enough coal to last 2000 years, but the position of oil is less hopeful, in which case a proportion of the coal may have to be converted into oil. The hydrogen bomb is now a fact, and vast supplies of energy could be drawn from deuterium and tritium, the supplies of which are seemingly inexhaustible. The earth's power supply will then become as unlimited as that of the sun. Every country would then have cheap power, so that vast uncultivated areas could produce enough food and goods to support twice the present population of the world, and at the same time allow the diminishing supplies of coal to be utilised for chemical purposes.

HARRY HOGGAN

Man and Energy

By A. R. Ubbelohde, F.R.S. (*London, Hutchinson's Scientific and Technical Publications, 1954, 247 pp., 18s.*)

The shortage of coal in Britain, which could have a very serious effect on our power supplies were it not for the promise of nuclear power in quantity in a few years, has led to a great interest in the general subject of energy. The germ of this book was the set of lectures which Prof. Ubbelohde (now at the Imperial College of Science and Technology, London) gave on the BBC Third Programme. These have amplified, and with the addition of copious excellent illustrations the result is a first-class book for the general reader who wants to learn about the progress of civilisation told in terms of man's ever-increasing ability to tap new sources of energy, and to exploit the old sources more efficiently. The first chapter establishes the historical perspectives of the development of power. A critical event in this story occurred about A.D. 1700; before that time, as Prof. Ubbelohde says, control of energy nearly always implied control of animal energy, but since then new methods began to be brought in and inanimate energy stored in coal, oil, etc., began to be tapped. Particularly interesting is the table in this chapter giving some of the most significant steps in man's conquest of energy. This chapter is followed by one discussing machines in the pre-metrical age (again there is an excellent table to summarise the key facts on the subject), and this leads on to Chapter III dealing with the development of steam power, turbines and electric power. Next the author considers the world reserves of energy. Chapters V–VIII discuss the social consequences of such technological developments and the character of Tektopia—a technological Utopia which has unlimited "energy-slaves" at its disposal and in which factory processes are automatically controlled.

The second part of the book is composed of six chapters covering the growth of scientific knowledge which has stimulated, and been stimulated by, the progress of the technological advances discussed in the first part. Here the reader will find very clear explanations of the Laws of Thermodynamics and of such concepts as entropy and "heat death".

Memoirs of a Birdman

By Ludwig Koch (*London, Phoenix House, 1955, 188 pp., 16s.*)

Millions of people have been enchanted by the songs of birds and animals which have come to their homes through the medium of the wireless and the gramophone. Only a privileged few have met and worked with the creator of the recordings, Dr. Ludwig Koch, as his

assistants in a kind of field work which he loves. Consequently, the vast majority of his listeners can have but little idea of the enormous amount of experience, patience, frustration, joy and despair which can go into the record of but a few seconds of bird call or song. Many may have wondered how this is done. Here, at last, is the book which gives the answer. In it we share the thrills of rare captures, such as the recording of the black redstart which sang one rainy evening from the sixth-floor balcony of Broadcasting House. We join with envy the recording party which was marooned in a gale on Skomer Island in company with the Atlantic seals and their babies. Koch voices the thoughts of all who heard this remarkable recording . . . "Suddenly a ghostly voice came to my ears. . . . I started recording. The longer I listened the more certain I became that the age-old stories of mermaids had come true. . . ."

We smile at the little wood-mouse which played with the microphone, an unexpected example of the many problems of outdoor recording which this patient scientist-musician has had to face. Here is the story of a unique experience by a pioneer who has attained an ambition as yet unfulfilled. Without disrespect one might call this book "The Autobiography of a monomaniac", for Ludwig Koch lives and dreams for his beloved birds. To record for posterity the voices of the wild, for all to hear and enjoy, has become his life's aim.

This lovely book ends with the thought that "Within my modest means I have helped to give practical expression to the sentiment expressed by John Keats when he sang of the nightingale—'Thou wast not born for death, immortal bird'." ALFRED LEUTSCHER

Biological Effects of External Radiation

Edited by Henry A. Blair (*New York and London, McGraw-Hill, 1954, 508 pp., 56s.*)

The volume is one of the National Nuclear Energy series which has been prepared as a record of research work done under the Manhattan Project and the Atomic Energy Commission of the United States. The studies reported in this volume represent the work carried out at the University of Rochester and at the Biochemical Foundation, Newark, during the war. The reports are concerned with the biological effects of single and chronic irradiation with x-rays and fast neutrons. The aim of the experiments, which involved investigations on a vast scale, has been to obtain information which could be used to devise effective protective measures for the great number of personnel who might be exposed to radiation during their daily work. Several of the reports it contains have already been published in scientific journals, but many others which have not previously been published have been either out-dated or greatly supplemented by more recent research owing to the great delay in declassifying them. The only value of this volume lies in the very extensive and detailed data concerning the rate of mortality and changes in blood of various mammals after acute and chronic irradiation.

P. C. KOLLER

Explaining the Atom

By Selig Hecht and Eugene Rabinowitch (*London, Gollancz, 1955, 224 pp., 12s. 6d.*)

The Man in the Thick Lead Suit

By Daniel Lang (*London, Gollancz, 1955, 207 pp., 13s. 6d.*)

Eugene Rabinowitch is well known throughout the world of science and to many more who are not scientists as the forthright editor and driving force of the Bulletin of the Atomic Scientists. There could have been no better choice of an author to bring up to date this book originally written by the late Prof. Hecht in 1947.

Hecht was Professor of Biophysics at Columbia University. His book has been rightly hailed as one of the most lucid yet written on nuclear physics for the lay reader. It needs no further testimonial than the fact that it has achieved eight large printings in seven years.

The original work presented a step-by-step historical treatment culminating with the manufacture and explosion of the first atomic bombs. "The number of these steps is small", wrote Hecht in his introduction, "and the ideas involved are simple. They can be described in all their essentials without assuming any knowledge of physics, chemistry or mathematics." Unlike so many who start off their books with such statements, Hecht went on to prove his point.

Rabinowitch discusses in a little more detail than did Hecht the other side of the picture and the "many exciting discoveries" that may lie around the corner. They add up, he says, to a "fascinating outlook for the not too distant industrial future. The fact remains, however, that atomic power plants, ships, and aeroplanes are future promises; but atomic and hydrogen bombs are dread realities". If freely used in a future major war, he warns, they would wipe out not only whatever atomic technology mankind might have developed by then, but the whole of the already existing civilisation as well.

If there is a criticism of this book it is that the "great and ominous shadow" of atomic war has been allowed to obscure too well the more cheerful and constructive side of the picture.

Of quite a different sort in Daniel Lang's book, *The Man in the Thick Lead Suit*. Lang made his name with a lively style that is typified in *The New Yorker*. His treatment of various subjects that include space rockets and flying saucers, but chiefly concern atomic energy, is essentially human. His chatty conversational style should not be allowed to mislead the casual reader into thinking that the book is of no consequence. Lang is a past master in the art of letting the man on the job tell his own tale, whether he be a German guided-missile man out to reach the moon, the Navajo shepherd who stumbles on a vast uranium deposit on his way into the Rattlesnake for his weekly supply of cigarettes, the Las Vegas croupier or the Oak Ridge physicist who decided to seek ordination in the Episcopal church. Daniel Lang is a first-rate reporter, and the men he interviews are all worth meeting. LEONARD BERTIN

Catalysis: Vol. 2.

Edited by Paul H. Emmett (*New York, Reinhold Publishing Corporation; London, Chapman and Hall, 1955, 473 pp., 96s.*)

The second volume of this series continues the treatment of fundamental principles. It begins with a classification of heterogeneous vapour phase reactions and for each class gives a full bibliography. Other chapters cover the nature of catalyst surfaces and the general theories of heterogeneous catalysis.

Although theory is emphasised, the intention of the work is still utilitarian. It will continue to find a welcome wherever industrial chemistry is practised.

Science Makes Sense

By Ritchie Calder (*London, Allen & Unwin, 1955, 192 pp., 12s. 6d.*)

Some people talk as though public interest in science is increasing rapidly, and yet at the same time there are others who claim that the gulf between scientists and non-scientists is growing all the time. Perhaps both things are happening, simultaneously, though this seems rather improbable. But one can be certain that the trend of events in recent years makes it most desirable that the public relations of science should be improved. An important contribution in this connexion has always been made by books of what, for lack of a better term, we call "popular science". In this field there is plenty to be done by both professional scientists with a flair for writing and by professional science writers. In Britain Ritchie Calder is an outstanding practitioner belonging to the second category, and this latest book of his can be warmly recommended to all who have enjoyed his earlier works.

At the outset Mr. Calder takes a glance back to the end of the 18th century when the Lunar Society was discussing everything under the moon and adding significant threads to the warp and woof of the Industrial Revolution. Of the members of that society, which included Erasmus Darwin, Josiah Wedgwood, Matthew Boulton, he says,

"Theirs was the spirit of universal inquiry, which somehow we have lost today in a world in which the common-ground of understanding has been fenced off into faculty-estates and a barrier wall has been built between the humanities and science." The whole volume amounts to an impressive argument for the view that science should be regarded as belonging to the humanities; certainly it succeeds in showing how much science has improved the lot of humanity.

The Geology of South Africa

By the late Alex. L. du Toit, edited by S. H. Haughton (*Edinburgh and London, Oliver & Boyd, 3rd edn., 1954, 611 pp., 41 plates, 63s.*)

At the time of his death in February 1948 Alexander du Toit was engaged on the revision and enlargement of his classic book on South Africa. He had actually written the preface in the January of the year of his demise, together with manuscript notes. Dr. S. H. Haughton undertook the task of completing the work and also the revision of the excellent geological map which accompanies the book. Geological exploration, always an active feature of South African geology, has brought forth many new facts since du Toit's death. Moreover, there has been considerable work done on the age-relations of many of the formations which conflict with the author's text. Dr. Haughton has very skilfully indicated these changes and trends of thought by a series of editorial footnotes to the more modern sources of literature dealing with these subjects. This has entailed an immense amount of work, and it is proper to record the debt geologists will owe to Dr. Haughton for his significant role in the production of this valuable revision of du Toit's original book. The editor must also be praised for including a list of the abbreviations used for footnote references, as these will serve to make easy the task of both geologist and mining engineer who wishes to make reference to these supplementary publications.

The book opens characteristically with a description of the major principles of continental geology and continental drift. The detailed treatment of the geology of South Africa proceeds systematically from a broad outline of the stratigraphical and structural units, south of the Zambesi, and surrounding the dry-lands of the Kalahari. Detailed treatment of the "primitive" or Archaean rocks takes the form of systematic description of the petrology and geographical distribution of these complicated groups of igneous and metamorphosed rocks. To the layman this presents difficulty as no attempt is made to dilute the scientific terminology current among geologists. This is praiseworthy, as all too frequently books of this character are marred by such efforts on the part of authors and publishers. Considerable attention has been given to problems of mineralisation, and in particular to the origin of gold-bearing deposits and the association of diamonds and kimberlites. Moreover a whole chapter is especially devoted to the economic geology of South Africa ranging over the gold, diamond and other gem-stone deposits; to the lead and zinc deposits of Broken Hill, the tin deposits of the Cape and the Bushveld, copper and many other valuable metals. In some ways this exciting aspect of the geology of South Africa has not been emphasised sufficiently, even in such a voluminous book. On the other hand, its contribution to basic geology and its discussion of the age relations of the rock formations leaves little to be desired. Substantial, factual and stimulating are the impressions which a study of this book will arouse; and it will help to emphasise the need for similar works of this kind dealing with other parts of Africa.

W. D. EVANS

NEW SCIENTIFIC INSTRUMENTS

In response to many requests from readers we are starting in this issue a new feature designed to provide information about new scientific instruments which have come on the market. The detailed data in this feature are the responsibility of the manufacturers, being taken from literature supplied by the makers. The editor will welcome information from manufacturers about new scientific instruments they are putting on the market. As these notes are intended for the large section of our readership composed of professional scientists, etc., we depart from our customary practice and use symbols and abbreviations to the full in order to be able to convey the maximum amount of detailed information.

Measurement of Heat Flow by Metallic Disks

This device for the direct measurement of heat flow consists of small disks 1 cm diameter and 0·15 cm thick, of a special tellurium alloy coated on each side with copper to which fine leads are attached, thus forming two opposed copper-tellurium alloy junctions. When heat passes through such a disk, at right angles to its surface, an e.m.f. is generated in the leads proportional to the temperature difference. This e.m.f. may be measured for small heat flows with a sensitive galvanometer, and for larger heat flows a potentiometric method is usually more convenient. Since tellurium has a high thermal e.m.f. against copper (about 500μV/°C) and a low thermal conductivity, sufficient sensitivity is attained. 1 B.t.u./sq.ft/h generates about 2·5μV. The internal impedance of the disks and leads is about 1Ω.

In their present form these heat flow disks may be used continuously for temperatures up to 100°C and intermittently up to 150°C. Investigations are proceeding on other materials for producing disks for use at higher temperatures. It is stated that the leakage of heat from furnaces, or into cold stores through the insulation of pipes, or from machinery may readily be obtained by means of embedded disks. Any number of disks may be connected in series to gain voltage and may be evenly spaced over an area to give an average reading. They are so thin that they acquire a surface temperature very close to that of the surrounding surface, while not appreciably affecting the air flow over that surface.

The disks may be used for measuring the heat from large, irregularly shaped surfaces, difficult to measure directly by other means, also from the bodies of man and animals by applying to the skin firmly with transparent tape.

The disks are available calibrated or uncalibrated. For relative measurements the latter, which are cheaper, suffice.

Joyce, Loebl & Co. Ltd., Vine Lane, Newcastle upon Tyne 1.

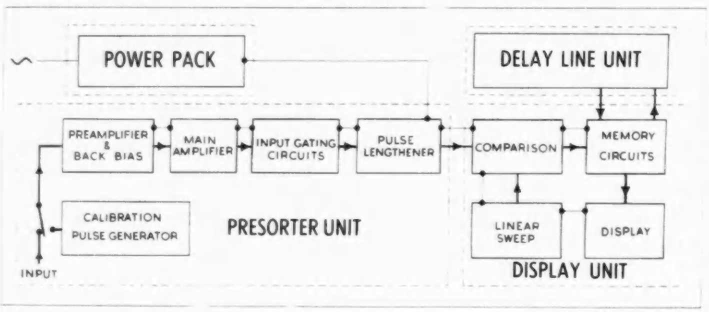
Electronic Pulse Height Analyser

The pulse height analyser, which is based on the design of Hutchinson and Scarrott (*Phil. Mag.*, 1951, vol. 42, 792), is a rack mounting instrument for the analysis of a complex pulse amplitude spectrum into groups of known height. It sorts the incoming pulses into groups selected to be 60, 80 or 120, according to their voltage amplitude. It comprises three main units, a power unit, a "presorter" or amplifier unit and a display unit (see diagram below).

The input pulse which is to be sorted passes in turn through a pre-amplifier with a gain of four, a biased amplifier which removes a controllable amount of the base of the pulse, an inverting amplifier of variable gain and a gate circuit, and is then fed into a pulse lengthener. A linear sweep circuit generates a voltage which is linear with time and the analyser measures the time interval from the beginning of the sweep until the sweep voltage equals the output voltage from the pulse lengthener. This interval is used to add unity to the appropriate binary number in the display.

The display is in the form of a raster of vertical lines on the screen of a cathode-ray tube, one line for each channel. The count in each channel is represented on a binary scale by an array of brightened dots. Each dot represents a "1" while a space represents a "0". The least significant figure in each channel appears at the bottom of the line and the pulse spectrum is approximately plotted on a logarithmic scale by the dots representing the most significant figure in each channel.

Sunvic Controls Ltd., Sunvic House, 10 Essex Street, Strand, London, W.C.2.



Corrosion Voltmeter for Buried Structures

This self-contained instrument, intended for field use, has been devised to measure the small electric potentials generated between a buried or immersed structure and its surroundings. Corrosion is basically an electro-chemical action and by measuring accurately the e.m.f. which gives rise to it, an estimate may be obtained of the location and extent of the corrosion taking place, and steps taken to minimise it. Since the e.m.f.s involved are very small, the instrument is designed to take no current from the circuit and employs a potentiometer that feeds to the circuit an equal and opposite e.m.f. to the corrosion voltage. It incorporates a high resistance Unipivot voltmeter having ranges of 1·2 and 5V together with a potentiometer connected in series with the corrosion voltage to be measured, and adjusted until the voltmeter reading is zero. This potentiometric "backing off" voltage is then measured on the voltmeter and is equivalent to the corrosion e.m.f. It is stated that with care satisfactory measurements may be made in circuits up to 1MΩ. The resistance when used as a directly connected voltmeter is 50kΩ on the 1·2V range and 208kΩ on the 5V range. Full-scale current is 24 μA. The current for the potentiometric circuit is supplied from a self-contained dry battery and is of the order of 10mA. It can also be used as a two range high resistance voltmeter in circuits of relatively low resistance.

This instrument has been developed in conjunction with Cathodic Corrosion Control Ltd.

Cambridge Instrument Co. Ltd., 13 Grosvenor Place, London, S.W.1.

A Reversible Aspirator

This small yet robust aspirator, which only weighs 1 lb, has been developed mainly for use with the standard model thermal precipitator, for obtaining dust counts in coal mines and similar environments, and especially for sampling the environments of workmen who have to move from place to place. It is about one-ninth the weight of the aspirator formerly used for this purpose, a great improvement in this respect. The general principle of the

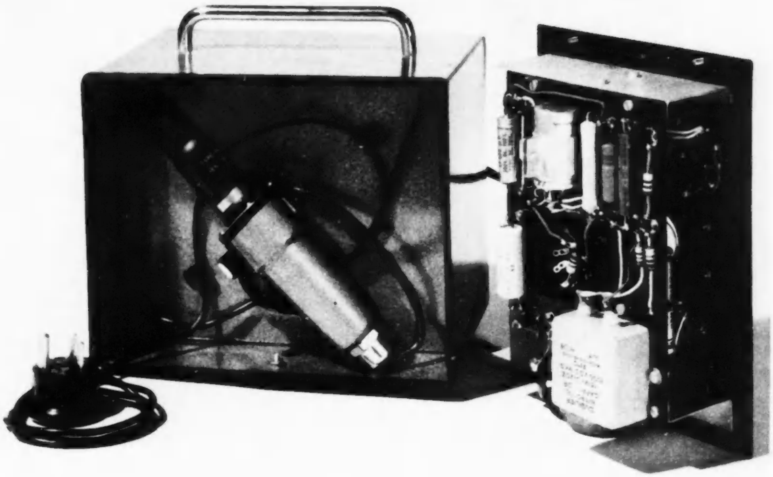


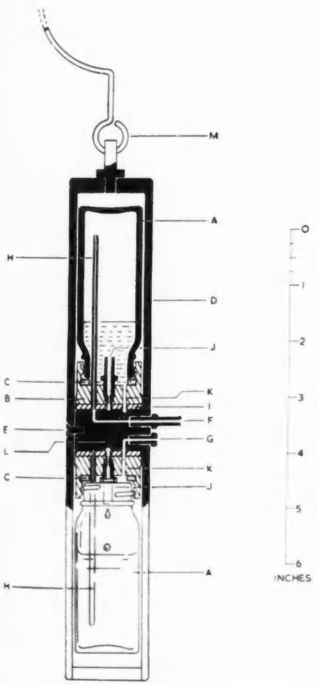
FIG. 1

I.D.L. RADIO-ACTIVITY METER

View showing interior of instrument and rear of cabinet with recess for probe unit and mains lead.

FIG. 2

WRIGHT REVERSIBLE ASPIRATOR



aspirator is comparable with that of a small vacuum pump, actuated by displacement of air. In practice a known volume of water is measured into one bottle and allowed to run out into a similar bottle placed underneath. By reversing the bottles the process may be repeated as often as required since the same water is used again and again.

The details of its design and construction are shown in Fig. 2. It consists of a central block of Duralumin *B*, lined with plastic *I* to eliminate the need for lubrication, into which identical Perspex bottles *A* are screwed. These are interchangeable with glass universal containers but are much more robust. The central stainless steel plug is bored in such a way that water can run from the upper bottle to the lower at the same time as air is drawn into the upper bottle through the inlet nozzle *F* and the air tube *H*, and expelled from the lower bottle by way of the hole *K* and outlet nozzle *G*. The protruding jets ensure that this goes on until the upper bottle is completely empty, when the volume of air aspirated will equal the volume of water measured initially into the bottle.

The instrument aspirates at a rate varying from 7 ml/min when full to 5 ml/min when nearly empty. Jets for different flow-rates and small-bore bottles for smaller volumes can also be supplied. The manufacturers state that the instrument is reliable and convenient in use, and provided clean water from a tap, preferably filtered, is used, the jets seldom become blocked. Should this contingency arise, however, they can easily be removed and cleaned with the key and pricker provided specially for the purpose. The Wright reversible aspirator is made from the design of Dr. B. M. Wright described in the *Journal of Scientific Instruments* (1954, vol. 31, 263), from which this figure is reproduced.

L. Adams Ltd., Minerva Road, London, N.W.10.

Radioactivity Meter

This simple instrument, shown in Fig. 1, of dimensions $9{\cdot}3 \times 8{\cdot}5 \times 6{\cdot}9$ inches and weight $7\frac{1}{4}$ lb. is an inexpensive radiation monitor consisting of a Geiger counter for β and γ rays and a ratemeter circuit employing a single cold-cathode trigger tube. It has been designed in collaboration with the Atomic Energy Research Establishment, Harwell, and the subcommittee of the British Science Masters' Association to provide the most suitable instrument for carrying out an illustrative range of experiments in connexion with radioactive isotopes, chiefly for educational purposes but will also serve as a general purpose monitor for β and γ rays, giving a useful accuracy for quantitative measurements.

The "I.D.L." radioactivity meter type No. 552 comprises a probe connected by 3 feet of cable to a ratemeter unit which operates directly from a.c. mains. The probe consists of a cast alloy unit carrying a Geiger counter socket and cable terminator which forms a convenient handle grip when the probe is used for searching, bench monitoring, etc. The counting rate is approximately 0–45 counts/s, for full-scale deflection of the meter, the integrating time constant approximately 30s and the accuracy when used in conjunction with the calibration chart provided is approximately $\pm 5\%$ of full-scale deflection. A flash indication can be observed in the trigger tube for each pulse from the Geiger counter.

Isotope Developments Ltd., Beenham Grange, Aldermaston Wharf, near Reading, Berks.

FAR AND NEAR

Night Sky in June

The Moon.—Full moon occurs on June 5d 14h 08m U.T., and new moon on June 20d 04h 12m. The following conjunctions with the moon take place:

June			
3d 09h	Saturn in conjunction with the moon	Saturn	6° N.
18d 19h	Venus	Venus	3° S.
21d 11h	Mars	Mars	3° N.
22d 12h	Jupiter	Jupiter	4° N.
30d 12h	Saturn	Saturn	6° N.

In addition to these conjunctions with the moon, Venus is in conjunction with Aldebaran on June 21d 11h, Venus 4°.6 N., and Mercury is in conjunction with Venus on June 30d 08h, Mercury 3°.8 S.

The Planets.—Mercury sets 21h 35m on June 1, about 1½ hours after sunset, but draws closer to the sun and is in inferior conjunction on June 16, so that it is not visible during the greater portion of the month. Venus rises at 3h, 2h 45m and 2h 40m on June 1, 15 and 30, respectively. Its stellar magnitude is −3·3 throughout the month, the visible portion of the illuminated disk increasing from 0·906 to 0·954, but this is offset by the increasing distance of the planet from the earth—from 140 to 151 millions of miles, in consequence of which the stellar magnitude remains the same. Mars sets at 22h, 21h 40m and 21h 15m at the beginning, middle and end of the month, respectively, but after the middle of June it is too close to the sun for favourable observation. Jupiter sets at 23h 20m, 22h 30m and 21h 40m on June 1, 15 and 30, respectively, in the latter case only 1h 20m after sunset when it cannot be favourably observed. Saturn, visible throughout the night, sets in the early morning hours, at 3h 05m, 2h 15m and 1h 10m on June 1, 15 and 30, respectively. It has a retrograde motion in Libra and towards the end of the month is near the star α Librae.

A total eclipse of the sun takes place on June 20. It is invisible in the British Isles, the path of totality crossing the Indian Ocean, Ceylon, Thailand and the Philippines.

Atomic News

The British Atomic Energy Authority and the French Atomic Energy Commission have concluded an agreement for the exchange of "unclassified information" on a range of subjects. The A.E.A. is to help the French Commission by giving advice and by supplying experimental quantities of various materials.

* * *

Sir Harold Himsworth, secretary of the Medical Research Council, is to be chairman of a committee set up by the council to prepare a report (to be published as a White Paper) on the medical aspects of nuclear radiation. The other committee members are:

Sir Ernest Rock Carling, Sir John Cockcroft, Prof. A. Haddow, Dr. J. F. Loutit, Prof. K. Mather, Prof. W. V. Mayneord, Prof. P. B. Medawar, Prof. J. S. Mitchell, Prof. L. S. Penrose, Sir Edward Salisbury, Dr. F. G. Spear, Prof. J. R. Squire, Prof. C. H. Waddington, Prof. Sir Lionel Whitby, Prof. B. W. Windeyer.

* * *

Press reports to the effect that agents of the American Federal Bureau of Investigation have been working at Harwell have been categorically denied by Government and Atomic Energy Authority spokesmen.

* * *

One of the most comprehensive exhibitions dealing with atomic energy ever held in Britain was opened in Thurso at the end of April. Opened by Mr. K. B. Ross, Director of Operations in the A.E.A.'s Industrial Group, it was designed to convey to the people of Caithness the significance of the Dounreay reactor against the background of the atomic energy programme.

* * *

The Australian and British Governments have agreed on the establishment of a new atomic testing ground in the desert country of South Australia. This will be known as Maralinga (an aboriginal word for "thunder") and will be situated to the north of the trans-continental railway line between Kingoonya and Deakin.

Element No. 101 Discovered

Element No. 101 has now been discovered, it was announced at the meeting of the American Physical Society on April 30. Like all its predecessors in the series of new elements with atoms heavier than those of uranium, its discovery depended on a nuclear synthesis achieved by bombarding heavy nuclei in the cyclotron.

The new element has been called mendelevium after Mendelev of "periodic table" fame. The discovery was made by Dr. Glenn T. Seaborg and his associates at the University of California. Seaborg, as readers will recall, has been connected with the discovery of several of the "heavier than uranium" elements, and for his work in this field he was awarded the Nobel Prize in 1951 for Chemistry (see Discovery, January 1952).

At the beginning of the last war no element heavier than uranium (Element No. 92 in the periodic table) was known. Early in the war neptunium (93) and plutonium (94) were discovered. Five more such elements were then synthesised—americium (95), curium (96), berkelium (97) and californium (98). The addition of Elements Nos. 99 and 100 to the list was announced in February 1954.

Research at Harwell

One of Harwell's staff, K. E. B. Jay, has now completed a triad of illustrated books for the general reader on atomic energy work in Britain. The latest volume, just published by Butterworths Scientific Publications, costs five shillings and is entitled *Atomic Energy Research at Harwell*. (His two previous books, published by Stationery Office, appeared in 1952 and 1954, and were respectively entitled *Harwell—The British Atomic Energy Research Establishment, 1946–51* and *Britain's Atomic Factories*.)

The new book is divided into two parts. The first, written primarily for non-technical readers is devoted to Harwell's major programmes. It provides interesting accounts of such things as the progress of Harwell's programme for isotope production and the application of these materials, and advances in the development of reactors. There is, for instance, a useful description of the heavy-water reactor E443 now in process of construction and due to operate next year. The second part deals in more detail with selected researches, and is intended for scientific readers, copious references being given at the end of each chapter.

Scottish Meteorological Society's Centenary

A hundred years ago the Meteorological Society of Scotland began life in Edinburgh. It was started as an experiment to test the amount of interest existing in Scotland on the subject of meteorology, and to ascertain what could be done by an organisation of voluntary individual observers. Thanks largely to the energy of the convener of council, Mr. D. Milne Home of Milne-Graden, and the secretary, Dr. James Stark, M.D., it achieved a great deal in its first three years. About seventy observers sent in their returns which were published for the benefit of all interested, including the newly formed Registrar-General's department.

It was then evident that the Society's policy should embrace a much wider programme. After some bargaining, a very small subsidy was paid by the Treasury (£200 a year) in consideration for certain services the Society rendered to public departments. The Society thus entered a new phase in 1858.

After several changes in the secretaryship, Alexander Buchan was appointed in 1861 and held the office until 1907, and throughout that period he enriched the Society's proceedings with the results of his own researches. Amongst his many writings perhaps the most widely known, and certainly the

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The Duke of Edinburgh's career as a patron of science, which started with his presidency of the British Association in 1952, continues to bring him into contact with more and more scientists and technologists. In recent weeks he has visited a number of laboratories, and he has officially opened the new buildings of the Medway College of Technology at Chatham (where this picture was taken) and the new laboratories of the British Rayon Research Association in Wythenshawe and the £530,000 block of chemical laboratories at Liverpool University.

most misquoted, are those in which he pointed out a tendency for the ordinary seasonal march of temperature to be interrupted on certain definite calendar dates.

The many interests of the Society can be followed in the published "Proceedings". Perhaps the most spectacular activity was the maintenance of the observatory on the summit of Ben Nevis (described by James Paton in DISCOVERY, April 1955).

The end of the Society as a separate body came in 1921. Some of the work for which it had been founded was now recognised as a Government responsibility, and the growth of the Meteorological Office (born in the same year as the Society) had been rapid during the First World War. It was felt that the Office should take over full responsibility for that work which the Society had done and received payment for. The council, faced with this loss of income and rising costs, recommended amalgamation with the bigger Royal Meteorological Society with its headquarters in London. The Scottish branch of the Royal Meteorological Society is, however, a live and active concern, and rightly celebrates the centenary of the parent Society this year.

A major feature of the celebration will be an exhibition "Scotland's Weather 1855–1955" in the Scottish National Museum, Edinburgh, from June 6 to 25, 1955.

New State Scholarship Arrangements

The financial position of State Scholars will be improved as a result of new arrangements set out in detail in Ministry of Education leaflet, *Administrative Memorandum, No. 502* ("Maintenance Rates for Students at Universities") published by the Stationery Office, price 4*d*. The new scheme will benefit many present and future science undergraduates. Last year 3325 State Scholarships were taken up, a large proportion of them by science students. The memorandum explains the rates of grant and methods of assessment for State Scholarships (including supplementary awards) and for the Ministry's further education and training awards to be introduced in the next academic year.

B.B.C. Plans for V.H.F.

On May 2 the V.H.F. station at Wrotham in Kent started regular transmission, thereby making it possible for some 13 million listeners to receive the Home, Light and Third Programmes on V.H.F. The service will be particularly welcome along the south coast where reception on the crowded medium waves is spoilt by interference from foreign stations. Ten such stations are due for completion by the end of 1956, and inside four years the B.B.C. hopes to make V.H.F. broadcasts available to 98% of listeners. So far Britain's radio industry has produced about 50,000 V.H.F. sets. The cheapest of these costs about £26. V.H.F. adaptors that can be fitted to ordinary radio receivers cost between £14 and £20.

The six transmitters for Wrotham have been made by Marconi's. When the installation is completed, one 25 kW. transmitter will handle the Light Programme and the other the Third Programme; two 10 kW. transmitters will operate in parallel to provide the Home Programme service, and two 4½ kW. units will be kept as stand-by equipment.

Non-Ferrous Metals Research

Among the newest research projects mentioned in the latest annual report of the British Non-Ferrous Metals Research Association is one concerned with the creep properties of zirconium alloys, and another dealing with titanium and titanium alloys. These are somewhat exceptional, however, for most of the Research Association's work is devoted to the more widely used industrial metals.

The report makes clear the importance of the organisation's liaison and information activities. The Information Department's function is to bring published information to members' notice, and its library lends large numbers of books, journals and papers through the post as part of the service. The Liaison Department on the other hand is more concerned with "know-how" and with putting existing knowledge to specific practical applications. These two departments account for about a third of this Research Association's income, as against two-thirds spent on research.

British Poisonous Plants

Losses and illness of farm stock caused by poisonous plants continue to engage the attention of farmers and veterinarians, and to simplify identification of such troublesome plants the Ministry of Agriculture has produced a bulletin (No. 161). This is entitled *British Poisonous Plants* and was written by Mr. A. A. Forsyth, formerly Professor of Veterinary Surgery at Glasgow University, and now Veterinary Consultant to the Food and Agriculture Organisation. It is published by H.M. Stationery Office, price 6*s*. 6*d*.

The Mescal Cactus

The hon. editor of the Cactus and Succulent Society of Great Britain, Mr. E. Shurly, has drawn our attention to an error of botanical nomenclature in the article on Mescalin (April 1955, p. 144). The mescal cactus was first described by Lemaire in 1845 under the name of *Echinocactus williamsii.* In 1885 its generic name was altered to *Anhalonium*, and in 1894 it was given its present name of *Lophophora williamsii. Lophophora lewinii* is a quite different species.

The British Association at Bristol

The preliminary programme for the Bristol meeting of the British Association, to be held from August 31 to September 7, is now obtainable from the organisation's office at Burlington House, London, W.1. This year's evening discourses will be given by Prof. C. F. Powell ("Experiments at Great

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